CORRELATES OF PHYSICAL ACTIVITY AND OBESITY IN CHILDREN AND ADOLESCENTS: A META-ANALYSIS AND MULTILEVEL ANALYSIS OF HONG KONG COMMUNITY FITNESS SURVEY

Daniel Chi Shing Yeung

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Doctoral Committee

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Aurelian Bidulescu, MD, PhD (Chair)

____

Zhongxue Chen, PhD

____

Noy S. Kay, HSD

____

Erik J. Nelson, PhD

June 3, 2019

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Daniel Chi Shing Yeung

CORRELATES OF PHYSICAL ACTIVITY AND OBESITY IN CHILDREN AND ADOLESCENTS: A META-ANALYSIS AND MULTILEVEL ANALYSIS OF HONG KONG COMMUNITY FITNESS SURVEY

This dissertation project investigated the association between physical activity (PA) and intention to engage in physical activity among children and adolescents, as well as possible correlates of obesity among high school students in Hong Kong. Two studies were conducted. Study 1 evaluated the association between PA and intention to engage in PA among children and adolescents, and the moderation effects of geographical region of study between PA and Reasoned Action Approach (RAA, Fishbein & Ajzen, 2010) -based variables. A total of 36 articles met the inclusion criteria and were meta-analyzed. Intention significantly correlated with and had a medium effect on PA in children. The RAA model displayed a good fit in path analysis. Moderator analyses showed that subjective norms and perceived behavioral control / self-efficacy had a larger effect on children in the rest of the world, compared to their North American counterparts. Study 2 examined potential individual-level and district-level correlates of obesity among high school students in Hong Kong. Data were obtained from the Hong Kong Community Fitness Survey conducted in 2010-2011. Age, sex, cardiovascular fitness, and district nitrogen dioxide concentration were the significant predictors in the final multilevel model. Compared to self-reported moderate to vigorous PA, cardiovascular fitness was found to be a better predictor of adolescents' body composition. The results provide a summary of current scientific findings about the association between RAA-based variables and PA in children and adolescents, and support RAA as a feasible conceptual framework to study psychosocial factors that underpin PA. Possible areas for future research are discussed.

Aurelian Bidulescu, MD, PhD (Chair)

Zhongxue Chen, PhD

Noy S. Kay, HSD

Erik J. Nelson, PhD

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CHAPTER 1:

EXECUTIVE SUMMARY

Background

Obesity is a worldwide growing epidemic (World Health Organization, 2014). It is one of the major contributors to the global burden of chronic disease and disability (Wang, McPherson, Marsh, Gortmaker, & Brown, 2011). According to Masters et. al (2013), overweight and obesity were likely responsible for about 18.2% of the United States (US) black and white adult deaths between 1986 and 2006. Findings from various reports concluded that overweight and obesity carry a profound health burden and will have a significant impact on health expenditures (Guh et al., 2009; Y. C. Wang et al., 2011). Obesity, however, is not only a public health problem for adults. It was estimated that 43 million children were overweight and obese worldwide in 2010 (de Onis, Blössner, & Borghi, 2010). Evidence demonstrates that child and adolescent obesity have adverse consequences on premature mortality and physical morbidity in adulthood (Reilly & Kelly, 2011). Obesity in children is independently correlated to endothelial dysfunction, inflammation and oxidative stress markers (Montero, Walther, Perez-Martin, Roche, & Vinet, 2012), and are associated significantly with increased risk of later diabetes, stroke, coronary heart disease, and hypertension, with hazard ratios ranged from 1.1 to 5.1 (Reilly & Kelly, 2011). A high prevalence of child and adolescent obesity are reported globally, including in the US and China, especially in economically developed countries and in urbanized populations (Ogden, Carroll, Kit, & Flegal, 2014; Wang & Lobstein, 2006; Wang, Mi, Shan, Wang, & Ge, 2006). In the US, among children and adolescents aged 2 through 19 years, 16.9% were obese (at or above the 95th percentile of the BMI-for-age growth charts) and 31.7% were overweight (at or above the 85th percentile of BMI for age) (Ogden et al., 2014). Recently, the extent of childhood obesity is so serious that estimated of extreme obesity was also reported (Ogden et al., 2016). Despite recent reports suggested the prevalence of childhood obesity in the US has plateaued, it stays at a high level with no sign to decline (Ogden et al., 2014, 2016).

The prevalence, however, differed by age and by race and ethnic group (Ogden et al., 2014). The prevalence of childhood obesity increased drastically in China in the last two decades (Ji & Sun, 2004). The problem is even more significant in urban areas. From the year of 1985 to 2000, the prevalence of childhood overweight in urban areas of China has increased from 1.13% to 10.38% for males and from 1.50% to 5.94% for females. In Hong Kong, the prevalence of childhood obesity has increased almost 70% in the past decade, from 13.4% to 22.5% for boys, and from 10.5% to 16.8% for girls, respectively (Yeung & Hui, 2007). The evidence above shows that childhood obesity is not merely a problem in the Western world, but is also a growing health problem in the Asian populations.

Lack of physical activity (PA) is known to be the main cause of obesity and also a leading cause of mortality. Mokdad and colleagues (2004) found that poor diet and physical inactivity was the second leading cause of death in the US (400,000 deaths; 16.6%). According to the American Heart Association, physical inactivity is a major risk factor for developing coronary artery disease and contributes to other risk factors, including obesity, high blood pressure, high triglycerides, a low level of HDL cholesterol and diabetes (Haskell et al., 2007). A sedentary person spends as little as 300 kcals per day in non-exercise activity thermogenesis (NEAT) compared with up to 2000 kcals for an active person (Black, Coward, Cole, & Prentice, 1996). The excess energy will be converted into body fat and stored in the body. Obesity is developed from prolonged positive energy balance. While the World Health Organization recommended that children and adolescents should do 60 minutes of MVPA daily (World Health

Organization, 2010), less than 20% of adolescents aged 11–17 years globally met the recommendation in 2010 (World Health Organization, 2014a). Encouraging children to be physically active should be one of the top priority tasks for healthcare professionals in the coming decades.

One major issue in studies involving obesity and PA is the difference in measurement methodology. While accelerometry are regarded as the gold standard of measurement, many studies still adopted self-reported questionnaires as the mean to capture participants' PA, possibly due to the unavailability of accelerometers, limitation of cost, and the extra time needed to collect, transfer and translate accelerometry data. For measurement of childhood obesity, the issue is even more complicated. Historically, cut-off points based on growth charts (e.g. gender-specific weight-for-height charts or BMI-for-age charts) have been applied as the indicators of overweight and obesity in children. The use of these local growth charts, however, makes comparison across country or region not possible. From a theoretical perspective, the use of these weight-height indices instead of body composition measurement to represent obesity status of children is questionable (Yeung & Hui, 2007, 2008, 2010).

While extensive effort has been made to study the factors associated with PA and obesity in children and adolescents, little has been done based on specific models and theories of behavioral change. The Ecological Models of Health Behavior (Sallis, Owen, & Fisher, 2008) could be applied in PA research and interventions. The ecological perspective emphasizes the environmental and policy contexts of behavior, while incorporating social and psychological influences. Ecological Models lead to the explicit consideration of multiple levels of influence but not solely focus on individual-level determinants. Individual level factors, or intrapersonal factors, are determinants that target to change one's personal attributes. Theories such as Social

Cognitive Theory (Bandura, 1986, 2004), and reasoned action approach (RAA) (Fishbein & Ajzen, 2010) (adapted from the Theory of Reasoned Action (TRA, Ajzen & Fishbein, 1980; Fishbein, 1980) and the Theory of Planned Behavior (TPB, Ajzen, 1991)), explore the relationship between health behavior and individual-level determinants such as beliefs, attitudes, subjective norms and self-efficacy. On the other hand, there are factors influencing health which are beyond the individual level, such as interpersonal factors (e.g. social support and family characteristics), institutional and community environments (e.g. work sites, schools, service systems and transportation) and social, economic, and political influences (e.g. laws and regulations, racism and discrimination). It is essential for researchers and practitioners to pay attention to determinants of different levels when conducting epidemiological analysis and intervention planning.

While RAA is theoretically sound and has been applied to other fields and health problems, a meta-analysis should be done to quantitatively synthesize the empirical studies available in physical activity contexts that have utilized all or some of the RAA measures. This would provide a summary of current scientific findings and fill the knowledge gap about whether RAA is a viable conceptual framework to study psychosocial factors that underpin physical activity and associated outcomes such as obesity in children and adolescents.

Besides, the influence of culture and ethnicity on PA should not be overlooked. Acculturation in the US has been identified as a risk factor for sedentary behavior and fast food consumption among Hispanic and Asian-American adolescents (Unger et al., 2004). Children and adolescents across different cultures and ethnicities would possibly possess specific determinants of PA and obesity. The individual-level and district-level correlates of obesity among adolescents should be explored through a large-scale population survey.

The two studies in this dissertation attempted to fill this knowledge gap. The results provided us a better understanding of how RAA perform in explaining PA in children across the globe. On the other hand, the blending of westernization and Chinese culture makes Hong Kong possibly an ideal site of studying these research questions. It provides a regional perspective for researchers, practitioners and policy makers about the determinants of childhood obesity in Hong Kong at multiple levels, which would be beneficial for the study of obesity and future development of evidence-based interventions and policies, as well as general city planning in Hong Kong, other metropolises in Asia, as well as overseas Chinese communities living in other Western countries.

Specific Aims of Dissertation

In this dissertation, two studies were conducted. Study 1 aimed to investigate the association between PA and obesity among children and adolescents, as well as the effect size between intention to engage in PA and PA among children and adolescents. The potential moderation effects of geographical region of study and ethnicity between RAA-based variables (i.e. intention, attitude, subjective norms and perceived behavioral control / self-efficacy) and PA were explored. In Study 2, the primary objective was to evaluate the association between various potential determinants of obesity and percentage body fat of high school students in Hong Kong. The study also aims to investigate whether these effects differ across regions in Hong Kong. Specifically, the studies attempted to address the research questions with the following specific aims:

Specific Aim 1. To examine the effect size (correlation) between intention to engage in PA and PA in children and adolescents. We hypothesized that intention to engage in PA has a positive effect on children and adolescents' PA.

Specific Aim 2. To examine among the RAA-based variables, the effect size (correlation) between attitude, subjective norms, perceived behavioral control / self-efficacy and intention to engage in PA among children and adolescents. We hypothesized that there is a positive but different magnitude of effect between attitude, subjective norms, perceived behavioral control / self-efficacy and intention to engage in PA among children and adolescents.

Specific Aim 3. To explore if there is any moderation effect of geographical region of study, sex, and age between RAA-based variables and PA. We hypothesized that these variables are possible effect modifiers of the association between RAA-based variables and PA.

Specific Aim 4. To investigate the individual-level as well as district-level correlates of obesity among adolescents in Hong Kong, through a citywide population survey and census data. We hypothesized that individual-level factors, such as student's MVPA, intention to exercise, sex, time spent doing homework, screen time, sleep quality, and family exercise participation, and district-level factors (i.e. air pollution levels, population density, and family mean income) are predictors of body fat percentage of adolescents in Hong Kong. We also hypothesized that the effect of these correlates on adolescents' body fat percentage differs across geographical districts of Hong Kong.

Significance of the Study

While there were extensive effort studying correlates of PA and obesity in children, few of them applied a theoretical and multilevel approach. Besides, the influence of geography region of study on PA should not be overlooked. Children and adolescents across different countries and ethnicities would possibly possess specific determinants of PA and obesity. The two studies in this dissertation attempted to fill this knowledge gap. Results from Study 1 provided a summary of current scientific findings about the association between intention, PA and obesity in children and adolescents worldwide. The information provided health theorists and professionals a better knowledge of how RAA perform in explaining PA in children, and understanding of if RAA is an appropriate approach to be applied in PA context. The results would also inform researchers about possible moderator variables of the association between RAA-based variables and PA, which would provide additional information on how these constructs interacts in different populations. Study 2, on the other hand, provided a multilevel perspective for researchers, practitioners and policy makers about the determinants of childhood obesity in Hong Kong and other Chinese communities. The findings are beneficial for future development of evidence-based interventions, school and government policies, as well as city design and planning.

Definition of Terms

Adolescence. Typically describes the years between ages 13 and 19 and can be considered the transitional stage from childhood to adulthood.

Attitude. Evaluation of an action as good or bad.

Body Composition. A component of physical fitness; absolute and relative amounts of muscle, bone, and fat tissues composing body mass. In this study, body composition is defined as the relative proportion of fat tissues in the body.

Body Mass Index. Body mass index (BMI) is defined as the individual's body weight in kilograms divided by the square of their height in meters.

Cardiovascular Fitness. The efficiency of the heart, lungs and vascular system in delivering oxygen to the working muscles. One of the main components of health-related fitness. Often referred as aerobic fitness.

Children. Young human being below the age of full physical maturity. In this study, children were defined as individuals aged between 9-19 years.

Childhood Obesity. In this study, the International Obesity Taskforce (IOTF) criteria (Cole, Bellizzi, Flegal, & Dietz, 2000) will be used to define childhood obesity. The age-specific BMI cut-off values for children were extrapolated from adult's BMI cut off points of 25 and 30 kg/m^2 for overweight and obesity.

Determinant. Factor or variable or construct might cause or facilitate the performance of a behavior.

Effect modification. A variable that differentially (positively and negatively) modifies the observed effect of a risk factor on disease status. Different groups have different risk estimates when effect modification is present.

Intention. Perceived likelihood of performing the behavior.

Moderate Intensity Physical Activity. Physical activity that is between three to six metabolic equivalents. It requires a moderate amount of effort and noticeably accelerates the heart rate.

Moderator. A variable that specifies conditions under which a given predictor is related to an outcome. The moderator explains 'when' a DV and IV are related. Moderation implied an interaction effect, where introducing a moderating variable changes the direction or magnitude of the relationship between two variables.

PACER. Progressive Aerobic Cardiovascular Endurance Run. Also known as multi-stage fitness test, bleep test or beep test, is a running test used to estimate an individual's cardiovascular fitness.

Perceived Behavioral Control. Belief about the extent to which one can control the performance of the behavior or that one is capable of performing the behavior.

Perceived Norm or Subjective Norm. Perceived social pressure to perform the behavior; overall normative influence.

Vigorous Intensity Physical Activity. Physical activity that is higher than six metabolic equivalents. It requires a large amount of effort and causes rapid breathing and a substantial increase in heart rate.

CHAPTER 2

REVIEW OF LITERATURE

Obesity

The epidemic of childhood obesity. Obesity is a worldwide growing epidemic (World Health Organization, 2014). It is one of the major contributors to the global burden of chronic disease and disability (Wang, McPherson, Marsh, Gortmaker, & Brown, 2011). In 2009-2010, the prevalence of obesity in the US was 35.5% among adult men and 35.8% among adult women (Flegal, Carroll, Kit, & Ogden, 2012). According to Masters and colleagues (2013), overweight and obesity were likely responsible for about 18.2% of the US Black and White adult deaths between 1986 and 2006. Findings from various reports concluded that overweight and obesity carry a profound health burden and will have a significant impact on health expenditures (Guh et al., 2009; Y. C. Wang et al., 2011).

Obesity, however, is not only a public health problem for adults. It was estimated that 43 million children were overweight and obese worldwide in 2010 (de Onis et al., 2010). Evidence demonstrates that child and adolescent obesity have adverse consequences on physical morbidity in childhood (Wake et al., 2013) and in adulthood (Park, Falconer, Viner, & Kinra, 2012; Reilly & Kelly, 2011). It was found that child and adolescent overweight and obesity were associated significantly with increased risk of later diabetes, stroke, coronary heart disease, and hypertension, with hazard ratios ranged from 1.1 to 5.1 (Reilly & Kelly, 2011). A high prevalence and increasing rates of child and adolescent obesity are reported globally, especially in economically developed countries and in urbanized populations (Ogden, Carroll, Kit, & Flegal, 2014; Wang & Lobstein, 2006; Wang, Mi, Shan, Wang, & Ge, 2006). In the US, among children and adolescents aged 2 through 19 years, 16.9% were obese (at or above the 95th percentile of the BMI-for-age growth charts) and 31.7% were overweight (at or above the 85th percentile of BMI for age). (Ogden et al., 2014). The prevalence, however, differed by age and by race and ethnic group (Ogden et al., 2014). Compared between NHANES 1976-1980 and NHANES 2003-2004, the prevalence increased from 5.0% to 13.9% for children aged 2-5 years; 6.5% to 18.8% for children aged 6-11 years; and 5.0% to 17.4% for adolescents aged 12-19 years (Ogden et al., 2016). Despite recent reports suggested the prevalence of childhood obesity in the US has reached a plateau, it maintains at a high level with no sign to decline (Ogden, Carroll, Kit, & Flegal, 2012; Ogden et al., 2014, 2016).

The prevalence of childhood obesity increased drastically in China in the last two decades (Ji & Sun, 2004). The problem is even more significant in urban areas. From the year of 1985 to 2000, the prevalence of childhood overweight in urban areas has increased from 1.13% to 10.38% for males and from 1.50% to 5.94% for females. In Hong Kong, the prevalence of childhood obesity has increased close to 70% in the past decade (Yeung & Hui, 2007). These show that childhood obesity is not merely a problem in the Western world, but is also a growing health problem in the Asian populations.

Obesity is closely associated with and is a risk factor for type 2 diabetes (Hajer, van Haeften, & Visseren, 2008; Kriska et al., 2003; Nguyen, Nguyen, Lane, & Wang, 2011). Obesity is strongly related to genetics and metabolic factors, and results from inadequate caloric expenditure and/or excessive caloric intake (Hajer et al., 2008; Weinsier, Hunter, Heini, Goran, & Sell, 1998). Obesity in children is independently correlated to endothelial dysfunction, inflammation and oxidative stress markers (Montero et al., 2012). Adipose tissue in the human body functions as an endocrine organ which produces hormones and cytokines involved in glucose metabolism, lipid metabolism, inflammation, coagulation, blood pressure and feeding behavior (Hajer et al., 2008). Lipids are accumulated in macrophages and adipocytes and cytokines are secreted from them. Compared to that of lean subjects, macrophages are more prevalent in adipose tissue of obese subjects (Otto & Lane, 2008). Large adipocytes release more saturated free fatty acids (FFAs) that can bind to macrophage toll-like receptor-4 (TLR-4). NF-κB is then activated which leads to increased production of tumor necrosis factor-α (TNF-α) (Suganami, Nishida, & Ogawa, 2005; Suganami et al., 2007). TNF-α activates human adipocytes and induces lipolysis and enhances the expression of various genes such as intracellular adhesion molecule-1 (ICAM-1), interleukin-6 (IL-6), macrophage chemoattractant protein-1 (MCP-1) (Permana, Menge, & Reaven, 2006; Ruan, Hacohen, Golub, Van Parijs, & Lodish, 2002). MCP-1 and ICAM-1 further facilitate the diapedesis of monocytes from the blood to adipose tissue and macrophage differentiation. Thus, the adipocyte dysfunction apparently leads to a pro-inflammatory state of adipocytes and macrophages. Chronically elevated FFA levels inhibit insulin secretion (Zhao, Feng, & Chen, 2006). *In vitro*, long-chain fatty-acyl-CoA and FFA can open β-cell potassium channels which diminish insulin secretion. FFAs elevate uncoupling protein 2 (UCP-2) expression, thus decreasing adenosine triphosphate (ATP) production necessary for secretion of insulin. β-cell apoptosis can also be induced by FFAs via an endoplasmic stress response and by inhibiting expression of the anti-apoptotic factor Bcl-2 (Zhao et al., 2006). Leptin has been shown to have anti-apoptotic effects in β-cells, which may be reduced in the (obese) leptin-resistant state (Hajer et al., 2008). The above review explains the pathophysiology of obesity and adipocyte dysfunction on type 2 diabetes.

Measurement of obesity in children. The only direct way to measure body fat percentage is through dissection, which is not feasible for living humans. There are different methods to estimate body fat percentage through the measurement of body density. Laboratory methods, such as hydrostatic weighing (or underwater weighing), dual energy x-ray absorptiometry (DXA) and hydrometry (estimation of total body water using doubly-labeled water), involve measurement of body density and are regarded as the “gold standards” of body composition measurement. There are limitations, however, of these laboratory methods. For example, participant is required to submerge his/her body completely into the water tank in hydrostatic weighing, including the head, which many children are unable to do. For hydrometry, a total of several hours are needed for completing the measurement. For DXA and ADP, expensive equipment and highly specified technicians are involved.

Lab measurement of body composition. *Hydrodensitometry.* Estimating body volume by hydrodensitometry, or underwater weighing, applies Archimedes’ principle. When a subject is submerged in water, the weight of displaced fluid is equals to the “loss” of weight contributed by the buoyancy force acting on the subject. Therefore, the body volume equals to the loss of weight in water. Hydrosensitometry is often regarded as the “gold standard” of body fat assessment (Heyward, 2001, 2006). It is relatively safe and low-cost. However, a number of technical issues make it not feasible for field testing. These limitations include: a) subject is required to submerge in water, thus making it not suitable for subjects who are not accustom to aquatic activity; b) a large water tank with a spring scale or a digital scale, heater, water circulator and filter are required; c) subject is required to perform maximal expiration underwater in order to obtain the underwater weight; d) it is time-consuming which makes it not convenient for mass testing.

Air displacement plethysmography. In contrast, air displacement plethysmography (ADP) by Bod Pod (Life Measurement System, Concord, CA) may be a preferable way than other body composition measurement method because of its fast measurement on land. It measures body volume and body density by using pressure-volume relationships (David Fields, Goran, &

McCrory, 2002). The Bod Pod consists of a single structure with two chambers: a test chamber and a reference chamber. During measurement process, the subject is required to sit in the test chamber, with minimal clothing and a swim cap to minimize the isothermal effects related to hair and clothing. Compare with hydrodensitometry, it is a more appropriate body composition method for young children because it is safe and easy to use, and no water submersion is required. ADP shows good to excellent reliability in measuring humans (Demerath et al., 2002). In both children and adults, between-day, test-retest correlation coefficient for body density and percent body fat generally exceeds r = .90. Wells and Fuller (Wells & Fuller, 2001) reported the precision of percent body fat to be 0.83% and 0.99% for boys and girls, respectively. In the study, it also found that precision was not related to body size because the precision for duplicate measurements in men and woman (0.99% and 0.76% body fat) was similar to children. Dewit and colleagues (2000) found that the precision of body volume measurements in children 7 to 14 years was 0.07 liters, which was as good as the precision for adults in the same study. These reports show that the precision of body volume measurement in children was as good as the precision of adults. ADP has been validated for the use with adults and demonstrated good precision when compared with hydrodensitometry, dual energy X-ray absorptiometry, and multicomponent models (Dewit et al., 2000; D a Fields & Goran, 2000; David Fields et al., 2002) The results of these available studies support ADP as a reasonable alternative to hydrodensitometry.

Hydrometry. Hydrometry is the measurement of total body water (TBW). Stable isotope labeled water, such as deuterium or oxygen-18, are commonly used. The concentration of these hydrogen isotopes in biological fluids after equilibration is measured to determine TBW. In children, Fat-free mass (FFM) hydration is a maximum from birth (~0.8) and declines rapidly during first few years to ultimately reach ~0.73 during teenage years (Sopher, Shen, & Pietrobelli, 2005). The isotope dilution method may not be the optimal method for assessing total body fat in children because of the wide variation in the hydration of FFM between individuals, despite the fact that they are the most reliable approach for estimating TBW (Hashimoto et al., 2002; LaForgia et al., 2004).

Dual energy X-ray absorptiometry. Dual energy X-ray absorptiometry (DXA) is originally a means of measuring bone mineral density (BMD). Two X-ray beams with differing energy levels are aimed at the participant's bones. BMD can be determined from the absorption of each beam by bone when soft tissue absorption is subtracted out. DXA is the most widely used and most thoroughly studied bone density measurement technology. DXA scans can also be used to measure total body fat and lean body content. Previous studies reported the correlation of DXA and hydrodensitometry were satisfactory (Lohman & Chen, 2005). Because of its lower amount of radiation exposure, DXA is a safe method to assess pediatric body composition. It is an alternative to the four-component model in pediatric population as it measures bone mineral content, lean soft tissue, and fat directly.

Other methods. There are other laboratory methods to measure body composition, such as neutron activation analysis, computed tomography and magnetic resonance imaging. These methods can produce images with high resolution. However, the procedures are not standardized. Moreover, they involve very expensive equipment and technical skill. Radiation exposure is also a concern for these methods.

Field measurement of body composition.

Field methods, though less accurate compared with laboratory methods, are much simpler and inexpensive. Field measurements can be carried out with a large group of people in school or community settings. Therefore, many larger-scale studies opted to use field methods due to their lower cost and convenience.

Bioelectric impedance analysis. The principle of bioelectric impedance analysis (BIA) is based on the relation of body composition to the body water content (Hoffer, Meador, & Simpson, 1969). With this method, low-level electrical current is passed through the subject's body, and the impedance, or resistance of current, is measured by an analyzer. Impedance will be greater for subject with more body fat, as adipose tissue is a poor conductor of electricity. Total body water is estimated and so fat-free mass can be predicted. Although BIA is a non-invasive and fast method for measuring body composition, its precision is affected many factors, including body position, hydration status, food or beverage consumption, ambient air and skin temperatures, recent physical activity, and bladder activity. Analyzers from different brands and companies show deviation in result (Graves, Pollock, Colvinl, Loan, & Lohman, 2005). Validation for the available equations in different systems against acceptable reference methods is required.

Skinfold thickness measurement. Scientists suggest the use of skinfold method in field setting as an alternative of laboratory method. Currently skinfold measurement is the most widely adopted field method of body fat measurement in children (Heyward, 2006). Since the instruments are portable, inexpensive and non-invasive, skinfold method can be readily applied in clinics, laboratories and schools. It is a measure of the thickness of two layers of skin and the underlying subcutaneous fat. It can be applied in both laboratory and field situations. It is a classic yet still widely applied body composition measurement method. The skinfold method indirectly measures the thickness of subcutaneous adipose tissue. Usually, skinfold thicknesses of different sites are collected.

According to Heyward and Stolarczyk (Heyward & Stolarczyk, 1996), there are several basic assumptions when using the skinfold method to estimate total body density to derive percent body fat: (1) The skinfold method is a good measure of subcutaneous fat; (2) The distribution of fat subcutaneously and internally is similar for all individuals within each gender; (3) There is a relationship between subcutaneous fat and total body fat, the sum of several skinfolds therefore can be used to estimate total body fat.

Skinfold thicknesses have high correlations with percent body fat (r = .7-.9) and do not differ among the common sites (Billisari & Roche, 2005). The distributions of adipose tissue and body proportion of children, however, differ from those of adults. Therefore, the prediction equations used to estimate percent body fat of adults are different than that used to estimate the fatness of children. Skinfold thickness measurements in children, with appropriate validated prediction equations, can be used to estimate body density and percent body fat (Sopher et al., 2005). Percent body fat estimated by these equations correlates well with percent body fat that determined by hydrostatic weighing (Harsha, Frerichs, & Berenson, 1978). Moreover, it is better predictor of body density than body circumference in children (Billisari & Roche, 2005). The validity and reliability of skinfold method are affected by technician's skill, type of skinfold caliper, subject factor, and prediction equation used to estimate body fatness. Standardized skinfold sites and procedures are recommended in the testing guidelines by the American College of Sports Medicine (American College of Sports Medicine, 2005).

Slaughter equations (Slaughter et al., 1988) are commonly used pediatric skinfold equations which uses multicomponent model reference measures. These equations may be used to assess the body composition of African American and Caucasian children aged 8 to 17 years old. They utilize the sum of triceps and calf skinfolds to predict the percent body fat of children. Yeung and Hui (2010) compared the body composition estimated from Slaughter equations with that measured by ADP in Chinese school children. While they found that skinfold measurement is a reasonable estimate of percent body fat and body density in Chinese children aged 9 to 19 years old, significant difference was found between the two estimations, and the slope of the regression line of Slaughter equation for boys was significantly different from the line of identity. Both the slope and intercept of prepubescent girls were significantly different from the line of identity. They concluded that the Slaughter equations are not applicable for Chinese children in Hong Kong. They then developed alternative skinfold prediction models for estimating percent body fat of Chinese children in Hong Kong, which combining anthropometric measurements and the children's age. The accuracy of these models is comparable to the Slaughter equations, and the estimated body composition by these alternative models was less deviated from the criterion measure than that estimated by the Slaughter equations (Yeung & Hui, 2010). It is so far one of the largest validation studies of skinfold equations for Chinese children.

Anthropometry. Anthropometry is the measurement of the size and proportion of the human body. It includes body height, body weight and body circumferences. Body mass index (BMI), derived from body weight and height, is a measure often used to determine childhood overweight and obesity. In the US, children obesity is defined as a BMI at or above the 95th percentile for children and teens of the same age and sex, based on the CDC Growth Charts (Kuczmarski et al., 2002) (Fig. 2.1). Overweight is defined as a BMI at or above the 85th percentile and below the 95th percentile for children and teens of the same age and sex. Extreme obesity was defined as a BMI at or above 120% of the sex-specific 95th percentile on the CDC BMI-for-age growth charts (Ogden et al., 2016).

Nevertheless, the CDC growth charts are local norm-referenced standards in the US and are not representative of other non-US populations. The International Obesity Taskforce (IOTF) established an international BMI cutoff for childhood overweight and obesity (Cole et al., 2000) (Fig. 2.3) based on six large nationally representative cross-sectional growth studies worldwide. The cutoff points were generated by extrapolation from adult BMI cut off of 25 kg/m^2 and 30 kg/m^2 for overweight and obesity. The IOTF cutoffs are comparably less arbitrary and more internationally based than other definitions, and are widely used in internationally comparative studies of childhood overweight and obesity (Yeung & Hui, 2008).

Weight-for-height index has been used in Hong Kong since 1993 (Leung, 1995; Leung, Lau, Tse, & Oppenheimer, 1996; Leung, Ng, Lau, & Tse, 1995; Leung, Tse, & Leung, 1996). Since then, childhood obesity in Hong Kong has been defined as having a body weight 20 percent higher than the median weight of the same height (i.e. 120% weight-for-height) (Fig. 2.2). Data from the 1993 Hong Kong Growth Survey (Leung, Lau, et al., 1996) was used as local reference to determine the criteria for the cut off points of childhood obesity until now.

The use of these weight-height indices to represent body fatness is limited, even though BMI is a predictor of cardiovascular disease and type 2 diabetes (Janssen, Heymsfield, Allison, Kotler, & Ross, 2002). It is because it does not account for the composition of body fat. It is found that percentage body fat was higher for a given BMI in South Asians compared with Europeans, whereas visceral adipose tissue was higher for a given waist circumference in both Chinese and South Asian men and women (Lear, Humphries, Kohli, & Birmingham, 2007). Persons having same BMI or weight-for-height in fact may have difference in body composition.

Physical Activity and Fitness

Insufficient Physical Activity. Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure (Sigal, Kenny, Wasserman, & Castaneda-Sceppa, 2004). Physical inactivity is known to be one of the main causes of obesity

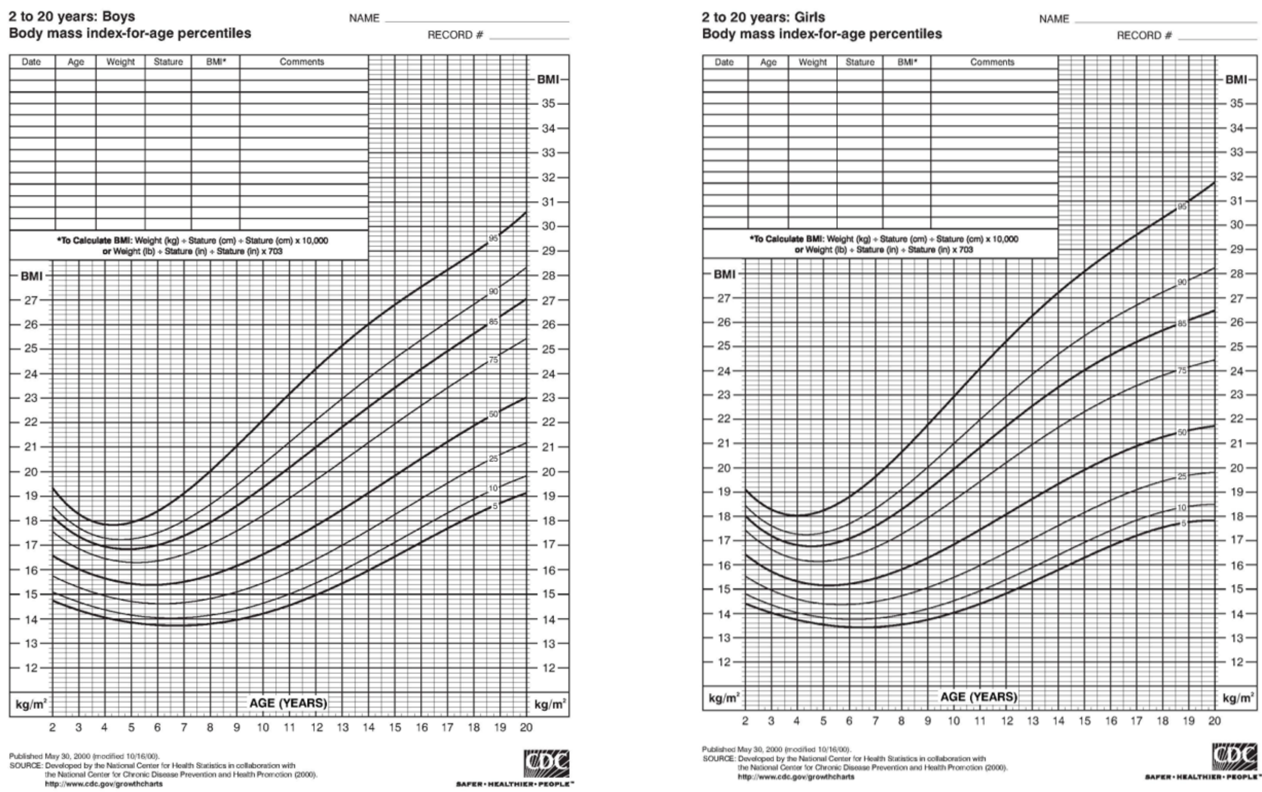

Fig. 2.1. The United States Centers for Disease Control and Prevention (CDC) BMI-for-age growth charts for boys and girls. Adopted from CDC website (www.cdc.gov/growthcharts).

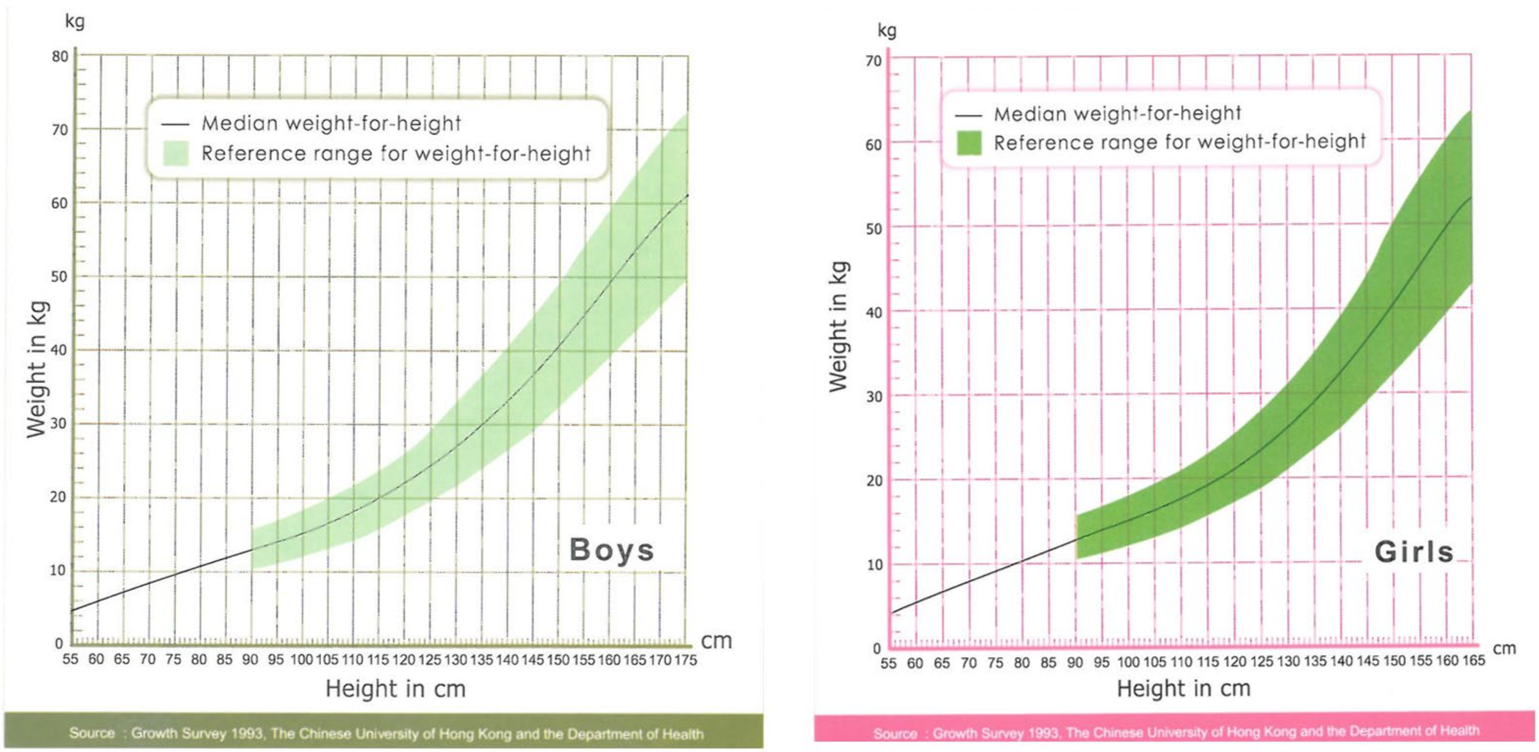

Fig. 2.2. Hong Kong Department of Health weight-for-height growth charts for boys and girls. Adopted from Hong Kong Department of Health website (www.chp.gov.hk/en/resources/e_health_topics/pdfwav_11016.html).

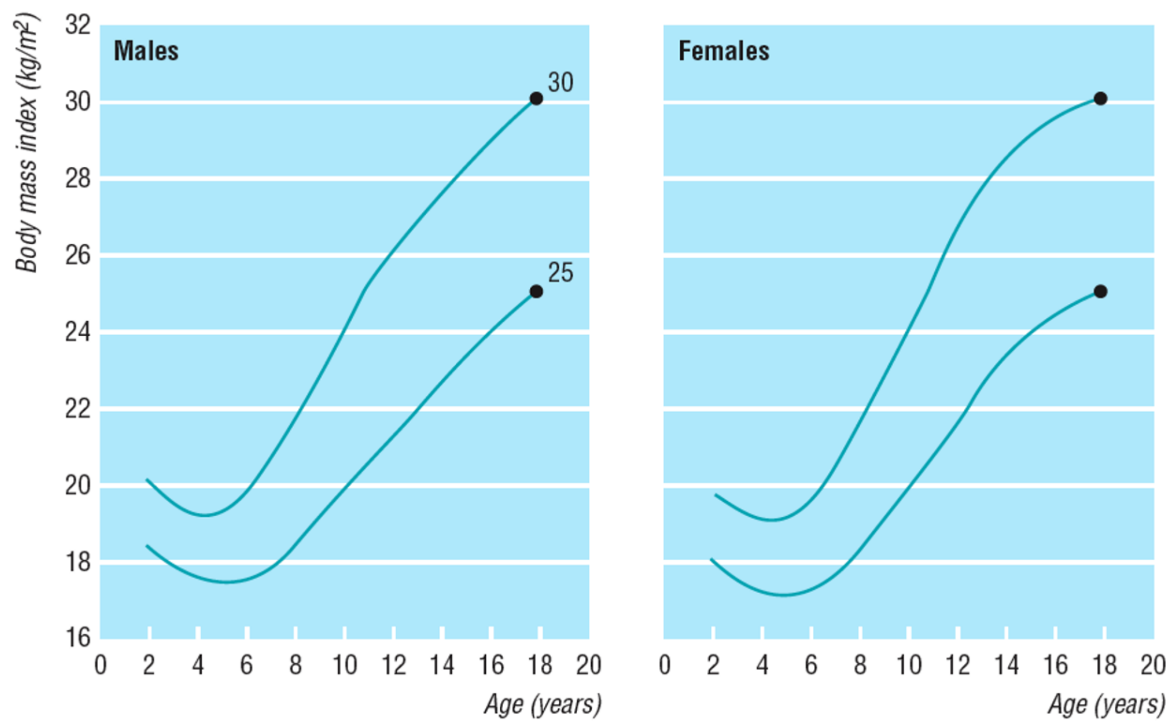

Fig. 2.3. International Obesity Taskforce (IOTF) overweight and obesity cutoff points for boys and girls. Data from Brazil, Hong Kong, Netherlands, Singapore and United States. Adopted from Cole (2000).

and also a leading cause of mortality. It caused more than 5.3 million of premature mortality worldwide in 2008 (I.-M. Lee et al., 2012). Mokdad and colleagues (2004) found that poor diet and insufficient PA was the second leading cause of death in the US (400,000 deaths; 16.6%). According to American Heart Association position stand, “Physical inactivity is a major risk factor for developing coronary artery disease. It also contributes to other risk factors, including obesity, high blood pressure, high triglycerides, a low level of HDL cholesterol and diabetes” (Haskell et al., 2007). A sedentary person spends as little as 300 kcals per day compared with 2000 kcals for a healthy person (Black et al., 1996). Inadequate caloric expenditure due to insufficient PA contributes to the development of obesity.

Evidence shows that increasing PA lowers the risk of mortality for diabetic patients and may substantially reduce the incidence of type 2 diabetes in high-risk individuals (Laaksonen et al., 2005; Sluik et al., 2012). Venables and colleagues (Venables & Jeukendrup, 2009) proposed that PA accelerates fat oxidation and reduces the accumulation of fatty acid species such as fatty acyl-CoAs, diacylglycerols and ceramides within the skeletal muscle, thus attenuating the inhibition on the insulin signaling pathway, or in other words, improving insulin sensitivity. However, PA also lowers the risk of type 2 diabetes by improving insulin sensitivity (Bassuk & Manson, 2005; Sigal, Kenny, Wasserman, Castaneda-Sceppa, & White, 2006; Venables & Jeukendrup, 2009). It is suggested that PA may have an important role in the prevention of type 2 diabetes through its association with reduced body weight and through independent effects on insulin resistance and glucose tolerance (Manson et al., 1991).

While the World Health Organization (WHO) recommended that children and adolescents should do 60 minutes of MVPA daily (World Health Organization, 2010), less than 20% of adolescents aged 11–17 years globally met the recommendation in 2010 (World Health

Organization, 2014a). According to the WHO, MVPA is defined as PA that is approximately three metabolic equivalents (METs) or higher, which requires at least a moderate amount of effort and noticeably accelerates the heart rate (World Health Organization, 2014b). Promoting MVPA among children and adolescents should be one of the top priority tasks for healthcare professionals in coming decades.

Measurement of Physical Activity and fitness in children. There are various ways of assessing PA level in children. The most widely used methods are self-reported measures, heart rate monitoring, pedometry and accelerometry.

Self-reported measures. Based on previous reviews on self-report measures of PA developed for children and adolescents (Kohl et al. 2000; Sallis & Saelens 2000; Sallis 1991), the validity coefficients ranged from 0.03 to 0.88 and reliability coefficients ranged from 0.56 to 0.93. It is suggested that objective measures of PA or parental-reported PA should be used in studies involving children 10 years or younger (Loprinzi & Cardinal, 2011).

The International Physical Activity Questionnaire (IPAQ) was developed to measure health-related PA in populations and is one of the most widely used questionnaires globally (Craig et al., 2003; Lachat et al., 2008; P. H. Lee, Macfarlane, Lam, & Stewart, 2011; Macfarlane, Lee, Ho, Chan, & Chan, 2007). It has a long form and a short form. The short IPAQ form (last 7-day recall) is recommended for national monitoring while the long form for research requiring more detailed assessment (Craig et al., 2003). A systematic review (P. H. Lee et al., 2011) has been done to examine the validity of IPAQ short form and found the correlation between the IPAQ-SF and objective measures of activity or fitness in the large majority of studies was lower than the acceptable standard. Furthermore, the IPAQ-SF typically overestimated physical activity as measured by objective criterion by an average of 84 percent.

The reviewers concluded that the evidence to support the use of the IPAQ-SF as an indicator of relative or absolute physical activity is weak.

Objective measures. Heart rate monitoring is an objective way to measure PA. Loprinzi and colleagues (2011) commented that the drawbacks of heart rate method are: (1) the variability across studies in the operational definition of resting heart rate and the protocol used to measure resting heart rate, (2) contribution of other factors that influence heart rate, and (3) the impracticality of using heart rate monitoring in large epidemiological and surveillance studies. Instead of using this method alone, scientists often incorporated heart rate measurement when using other methods such as pedometry or accelerometry (Butte, Ekelund, & Westerterp, 2012; Plasqui, Bonomi, & Westerterp, 2013).

Following technological advancement, the cost of motion sensors, including pedometers and accelerometers, has gone down and becomes more affordable to the population. The objective nature of this method makes it a better option compared to self-report measures (Eston, Rowlands, & Ingledew, 1998). The compact size of these devices give subjects little burden compared to indirect calorimetry or hydrometry (using doubly labeled water). Feasibility of incorporating accelerometry in large scale studies has been demonstrated (Mattocks et al., 2008) and national surveys of various countries, including the US (Barreira, Katzmarzyk, Johnson, & Tudor-Locke, 2013) and Canada (Colley et al., 2011) have adopted accelerometer data as a part of their national health surveillance system.

In 2013, the American Heart Association released a scientific statement on assessing PA (Strath et al., 2013). It emphasizes the importance of monitoring PA, describes the advantages and disadvantages of different methods in detail, and provides a comprehensive guide on choosing an appropriate PA assessment method depending on situations. It emphasized that there is no single best assessment method for all circumstances, and multiple methods may have to be used together to provide reasonably accurate results.

Measurement of cardiovascular fitness. Many studies in previous decades, despite the above statement, measured cardiovascular fitness (or aerobic fitness / cardiorespiratory endurance) instead of PA to reflect individuals' physical health. This might be due to the fact that in the field of exercise science, cardiovascular fitness, has long been regarded as one of the major components of health-related fitness (Ruiz et al., 2009). In terms of measurement of aerobic fitness, measurement of maximal oxygen uptake (VO2max) is the most widely used measure of physical fitness, as it indicates the maximal capacity of the cardiovascular system to provide oxygen to muscle cells during sustained exercise. VO2max is usually measured by an incremental test on a motor-driven treadmill or a cycle ergometer in laboratory setting. This measure is performed using continuous sampling and analysis of expired air and measurement of ventilation. The major disadvantages of this method are the requirement of expensive exercise ergometers, gas analysis and ventilation equipment, and the need for medical attendance (Ekmekcioglu & Haber, 2002).

Given these disadvantages for direct measurement of VO2max, attempts have been made to estimate VO2max outside laboratory settings by field measurement. VO2max of individual is predicted from the result of field test, either by elapsed exercise time or distance traveled. It is based on a linear relationship between the exercise intensity and oxygen uptake. The advantage of adopting field tests is that minimal equipment is required to evaluate the aerobic capacity of individuals. It can be easily performed, and multiple subjects can perform the test at the same time.

Field tests can be classified into two categories: submaximal tests and maximal tests. Maximal tests require the participant to exercise to exhaustion. These tests, such as Cooper 12-minute swim test (Huse, Patterson, & Nichols, 2000), showed mediocre correlation with VO2max. Running tests which require participants to run for about 2.4 km, such as 1.5 mile (1.609 mile) run and Cooper's 12-minute run, shows better correlation (Mayorga-Vega, Bocanegra-Parrilla, Ornelas, & Viciana, 2016). In children and adolescents, Progressive Aerobic Cardiovascular Endurance Run (PACER), also called multi-stage fitness test, bleep test or beep test, is the most popular field fitness test for aerobic fitness. The original form of PACER is a 20-meter shuttle run test (Léger, Mercier, Gadoury, & Lambert, 1988). A 15-meter PACER protocol is also available for schools with limited space. PACER is the recommended test for aerobic capacity in the FITNESSGRAM assessment battery (Cureton, Plowman, & Mahar, 2013; Meredith & Welk, 2010). Based on the above review, both PA and cardiovascular fitness were investigated in this dissertation.

Theoretical Models of Health Behavior

Ecological Models of Health Behavior. Ecological Models of Health Behavior (Sallis et al., 2008; Figure 2.4) emphasize the environmental and policy contexts of behavior, while incorporating social and psychological influences. Ecological Models lead to the explicit consideration of multiple levels of influence but not solely focusing on individual-level determinants. According to Sallis, the four core principles of ecological models of health behavior are: (1) There are multiple influences on specific health behaviors, including factors at the intrapersonal, interpersonal, organizational, community, and public policy levels; (2) Influences on behaviors interact across these different levels; (3) Ecological models should be behavior-specific, identifying the most relevant potential influences at each level; and (4) multilevel interventions should be most effective in changing behavior.

Individual Factors. Individual level factors, or intrapersonal factors, are determinants that target to change one's personal attributes. Theories such as Health Belief Model (Hochbaum, Kegels, & Rosenstock, 1952; Rosenstock, 1974), Theory of Reasoned Action (TRA, Ajzen & Fishbein, 1980; Fishbein, 1980), Theory of Planned Behavior (Ajzen, 1991) and Social Cognitive Theory (Bandura, 1986, 2004) explore the relationship between health behavior and individual-level determinants such as beliefs, attitudes, subjective norms and self-efficacy.

Health Belief Model. The Health Belief Model (Hochbaum et al., 1952; Rosenstock, 1974) is one the earliest and most used theories of health behavior. It was developed by social psychologists at the US Public Health Service expressly to understand why people were not taking desired health actions. Having its origins in social psychology, it is an example of an expectancy-value theory reformulated specifically for health actions. It has been used for many different health actions from preventive to early detection to treatment actions. The key principles include: (1) A person will take a recommended health action (to prevent, screen for, or control a health condition) if they perceive themselves as under threat of the condition and if the perceived benefits of the action outweigh the perceived barriers; (2) The perceived threat of a condition is a result of perceived susceptibility to the condition and the perceived severity of the condition; (3) Perceived benefits minus the perceived barriers is the calculated variable that is a result of the subtracting barriers from benefits. The issue of this model in physical activity context is that there are other important factors influencing physical activity that should be

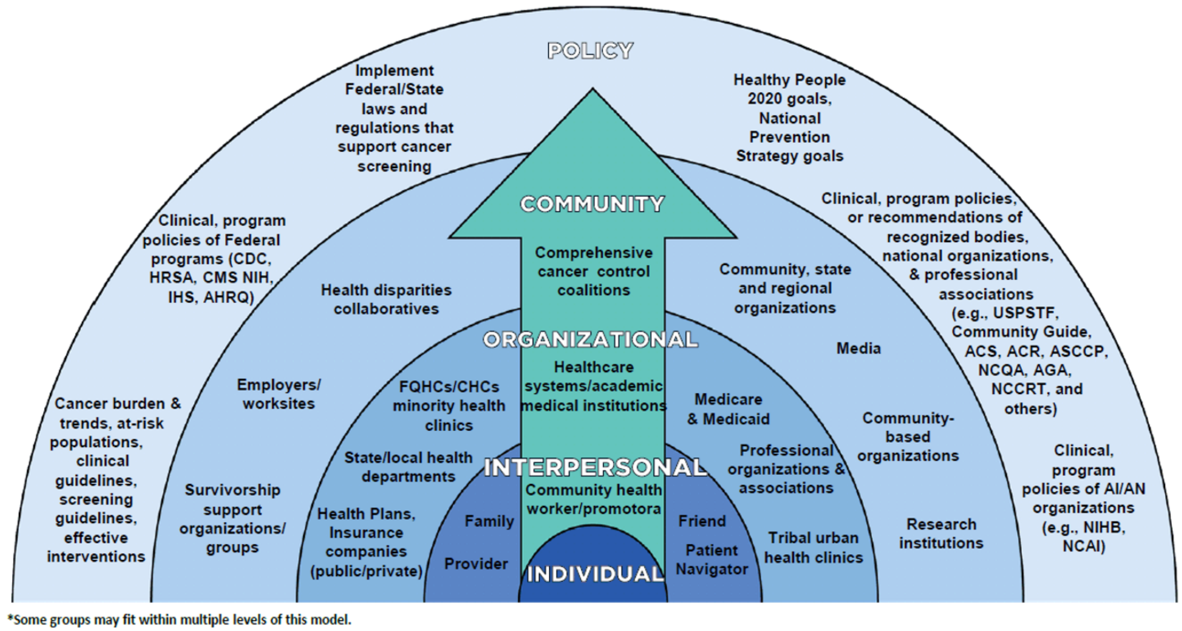

Figure 2.4. CDC's social ecological model of health promotion, representing the Colorectal Cancer Control Program's (CRCCP's) multilevel approach to colorectal cancer prevention. (Joseph et al., 2011)

identified, apart from perceived benefits, perceived barriers, and cues to action (Ar-yuwat, Clark, Hunter, & James, 2013).

Social Cognitive Theory. The Social Cognitive Theory (Bandura, 1986, 2004) was originated from Social Learning Theory. In traditional learning theory, an individual acted and was reinforced directly. Bandura argued for an interpersonal form of learning in which learning occurs by observation or vicariously. People can learn by observing others take actions and receive rewards. In this early work, the theory was used in therapeutic settings to help people deal more effectively with fears and phobias. In 1986, Bandura renamed the theory, Social Cognitive Theory, to reflect the increasing role of cognitive concepts, in particular self-efficacy. It is one of the most used theories in health behavior. In fact, self-efficacy has been added as a construct to several other theories. A study suggested that social cognitive theory constructs were better predictors of physical activity than those from the theories of reasoned action and planned behavior (Dzewaltowski, Noble, & Shaw, 1990). Nevertheless, a recent review (Beauchamp, Crawford, & Jackson, 2019) suggested five critiques and contentions related to Social Cognitive Theory. They are: (1) Self-efficacy beliefs and goal pursuits; (2) Self-efficacy beliefs and outcome expectations: issues of directionality; (3) The role of sociostructural factors in Social Cognitive Theory; (4) Within-person effects of self-efficacy: evidence of performance buffering? and (5) Assessment: are typical self-efficacy measures confounded? The reviewer summarizes that the model could be revised and refined based on the recent findings in the field.

Theory of Reasoned Action. The Theory of Reasoned Action (TRA, Ajzen & Fishbein, 1980; Fishbein, 1980) in Figure 2.5 was developed within social psychology at a time when the concept of attitude was being challenged because of the weak association between attitudes and behavior. TRA made three contributions to the behavioral prediction literature: (1) identified

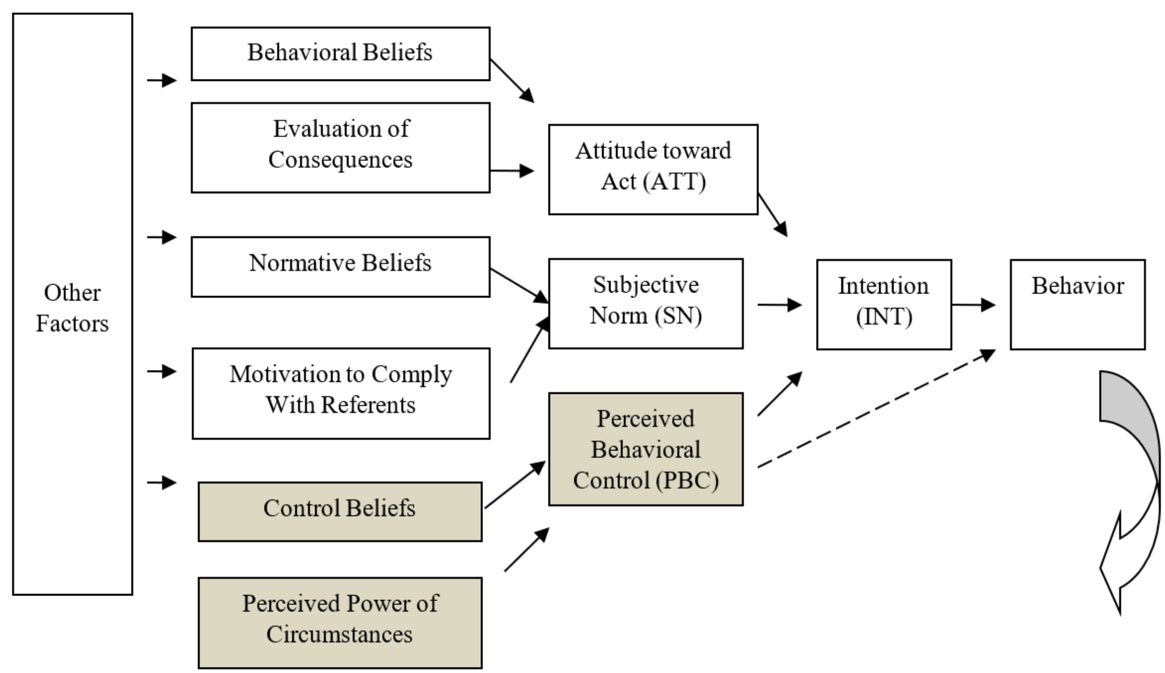

Figure 2.5. The Theory of Reasoned Action (Ajzen & Fishbein, 1980) (constructs in white) and Theory of Planned Behavior (Ajzen, 1991) (added constructs in yellow).

intention as the immediate determinant of behavior; (2) differentiated attitude toward an object from the attitude toward performing the behavior; (3) added normative factors. TRA is best used with actions that are under voluntary control, that are well-defined, and that correspond to the behavior under study in action, time, context, and object.

Theory of Planned Behavior. The Theory of Planned Behavior (TPB, Ajzen, 1991) is an extension of the TRA developed to deal with situations in which the behavior under study is not completely under volitional control. TPB made two contributions: (1) added perceived behavioral control as a determinant of behavior AND of intention; (2) outlined specific determinants underlying perceived behavioral control.

The issue of these individual level theories is, while they have a long history and are quite well researched, they overlook the significance of other external and environmental factors, as well as constructs proposed by other intrapersonal level theories. Therefore, each of these theories can only explain a certain part of the whole picture of the health problem.

Beyond Individual Level. There are factors influencing health which are beyond the individual level, such as interpersonal factors (e.g. social support and family characteristics), institutional and community environments (e.g. work sites, schools, service systems and transportation) and social, economic, environmental and political influences (e.g. laws and regulations, racism and discrimination).

Tandon and colleagues (2012) suggested that lower socioeconomic status (SES) promotes sedentary behavior. Children in low SES families had a daily screen time (time spent computer and/or TV) of 2.4 hours per day, compared to 1.7 hours per day for children in high SES families. Kelly and colleagues (2006) tested the hypothesis that habitual PA and/or sedentary behavior are associated with SES in young Scottish children. However, the result showed SES was not a significant factor in explaining the amount of time spent in PA or sedentary behavior once gender and month of measurement were taken into account. More studies are needed to be done to investigate the effect of SES on childhood obesity. Tudor-Locke and colleagues (2003) found that Chinese children rarely participated in MVPA outside of school. They did not perform housework at home, which is unique compared to those in other developing countries. It is also found that they were under pressure to achieve academically. This is an example of socio-cultural influence of PA in children.

Environmental factors also play a huge role in PA and obesity. Fine particulate air pollution is a risk factor for cause-specific cardiovascular disease mortality via mechanisms that likely include pulmonary and systemic inflammation, accelerated atherosclerosis, and altered cardiac autonomic function (Pope et al., 2004; Pope & Dockery, 2006). A current review (Tanwar, Katapadi, Adelstein, Grimmer, & Wold, 2018) concluded that particulate matter exposure can have both direct and indirect effects on human health, and even greater effects in susceptible populations. In terms of PA in children, severe ambient air pollution may lead to cancellation of physical activity or sports for schoolchildren, since most physical education curricula are outdoor-oriented. That may in turns constitute to the increase of overweight and obesity (Li, Liu, Lü, Liang, & Harmer, 2015).

The Integrative Model. Figure 2.6 is the integrative model of behavior prediction (Fishbein, 2008; Fishbein & Ajzen, 2010). The model was the latest development of the reasoned action approach (RAA), adapted from TRA and TPB, with external and environmental factors incorporated into the model. According to the authors, the integrative model attempts to identify a relatively small set of variables that can account for a substantial proportion of the variance in

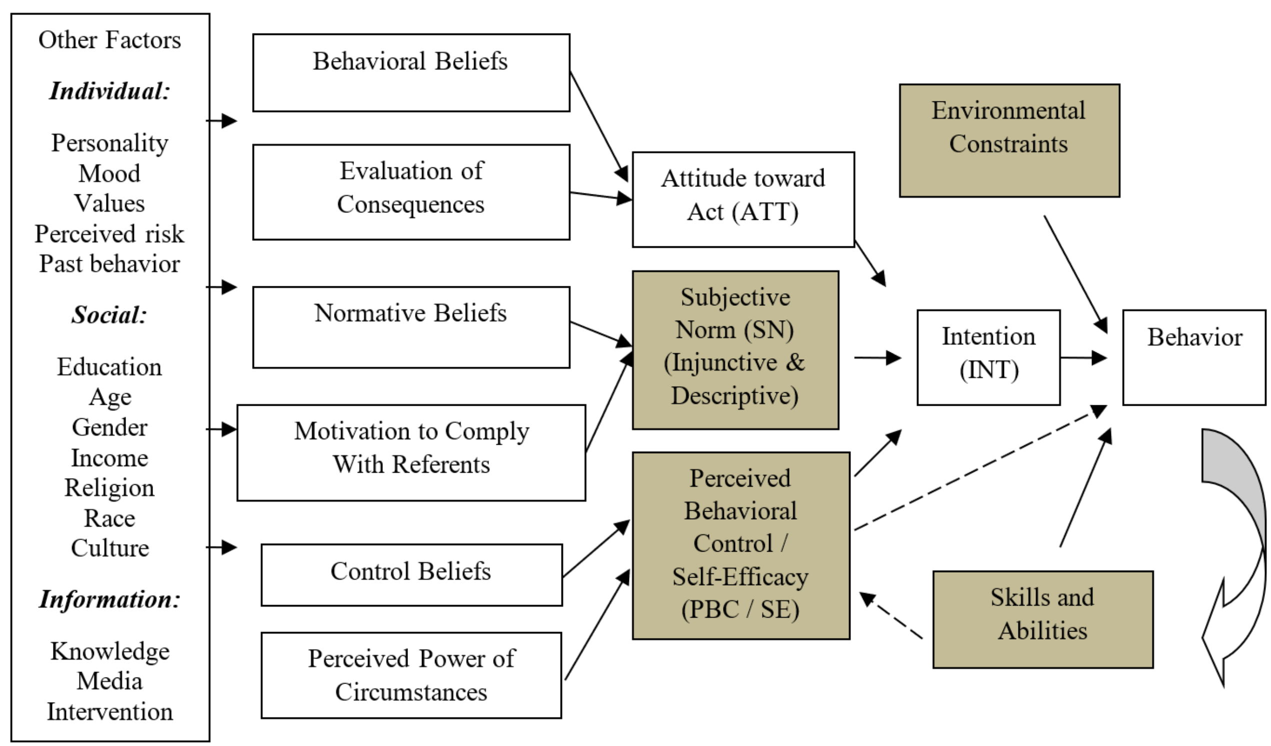

Figure 2.6. The integrative model of reasoned action approach. Adapted from Fishbein (2008) and Fishbein and Ajzen (2010) .

any given behavior. The integrative model, along with the transtheoretical / stages of change model (Prochaska & Velicer, 1997), social cognitive theory (Bandura, 1986, 2004) and the health belief model (Hochbaum et al., 1952) are the most widely used theories in the field for the purposes of explaining and predicting a variety of health behaviors, and have been broadly applied to design health behavior change interventions.

According to the model, intention is the immediate determinant of behavior. Intention is the perceived likelihood of performing the behavior. It is influenced by a person's attitude toward performing a behavior, by beliefs about whether individuals who are important to the person approve or disapprove of the behavior (subjective norm), and by people's beliefs that they can control a particular behavior (perceived behavioral control). Attitude toward the act is influenced by behavioral beliefs (about consequences) and outcome evaluations (of consequences). Subjective norm is the perceived social pressure to perform the behavior. There is injunctive norm (belief about whether most people who are important expect the person to perform the behavior; perceptions of what others think I should do) and descriptive norm (belief about whether most people like me actually perform the behavior; perceptions of what others do). They are influenced by their corresponding normative beliefs and motivation to comply with referents. Perceived behavioral control or self-efficacy is the belief about the extent to which one can control the performance of the behavior or that one is capable of performing the behavior (not the degree that performance of the behavior will lead to attainment of goal). It is influenced by control belief strength (perceived likelihood of occurrence of each salient facilitating or constraining condition) and perceived power (perceived effect each condition has on making the performance of the behavior easy or difficult).

The main difference between the integrative model and its predecessors is the addition of external variables and environmental constraints into the model, addressing Sallis' ecological multilevel approach. The three important characteristics of RAA are: (1) They are general theories of behavior that have been used in areas outside of health and that have been applied to understand and influence many behaviors for many issues; (2) They have strong measurement models based on semantic differential and Likert-type measures of cognitions or beliefs (likely/unlikely or agree/disagree) and attitudes or evaluations (good/bad) and use an expectancy-value approach to measure the underlying belief structure; (3) When measured, all of the constructs need to be compatible with the behavior in terms of action, target, context, and time.

While RAA is theoretically sound and has been applied to other fields and health problems, a meta-analysis should be done to quantitatively synthesize the relatively large volume of empirical studies available in physical activity contexts that have utilized all or some of the RAA measures. This would help fill the knowledge gap about whether RAA is a viable conceptual framework to study psychosocial factors that underpin physical activity and associated outcomes such as obesity. Such evidence can inform epidemiologists, health promotors and clinical practice regarding the goals of physical activity promotion.

CHAPTER 3:

PSYCHOSOCIAL CORRELATES OF PHYSICAL ACTIVITY IN CHILDREN AND ADOLESCENTS: A META-ANALYSIS

Introduction

As mentioned in previous chapter, the Reasoned Action Approach (RAA) is a theory developed within social psychology, which is evolved from the Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB), and widely applied in health promotion. In this study, we investigated the association between physical activity (PA) and intention to engage in PA among children and adolescents using TPB/RAA as the framework. The effect sizes of PA and the main constructs of RAA (i.e. intention, attitude, subjective norms and self-efficacy / perceived behavioral control) were consolidated and meta-analyzed. The potential moderation effects of age, sex, mode of PA measurement, study design and country where the study conducted were also explored.

Methodology

Inclusion criteria. While all study types were included, studies had to meet the following criteria for inclusion in this study. First, participants had to be aged 19 years or younger. Second, studies had to measure participants' intention to engage in PA. Protocol papers, review papers and studies that did not measure intention to engage in PA were excluded.

Selection of studies. A search of online databases (MEDLINE/PubMed, SPORTDiscus, ERIC, PsycINFO and PsycARTICLES) for all available years were conducted in the Summer of 2016 to identify studies that were to be included in the meta-analysis. Three filters were used involving combinations of search terms. The first filter, for study population, used the following search terms: child OR youth OR adolescent OR adolescence OR teen OR student. The second filter, for studies related to PA, used the following search terms: physical activity OR exercise. The third filter, for studies with measurement of intention, used the following search terms: intention OR reasoned action OR planned behavior.

Ancestry (using the reference lists at the end of acquired articles) and descendancy approaches (looking for relevant studies that have cited acquired articles) were used to supplement the computerized literature searches.

Meta-analytic strategy. The meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. Relevant papers were entered into EndNote X7. Zero-order correlations between intention (i.e. perceived likelihood of performing PA), attitude (i.e. evaluation of performing PA as good or bad), subjective norms (i.e. perceived social pressure to perform PA), self-efficacy / perceived behavioral control (i.e. belief about the extent to which one is capable of performing PA, or that one can control the performance of PA), and PA were retrieved by the principal investigator as estimates from each study. The zero-order correlation coefficient was selected as the effect size to be considered as it was the most common metric presented in the studies. Effect size thresholds were determined based on Cohen's (1988) interpretation. (i.e. $r < 0.10$: trivial; $0.10 \geq r > 0.30$: small; $0.30 \geq r > 0.50$: medium; $0.50 \geq r > 0.70$: large; $r \geq 0.70$: very large). All study types were included. For studies or cohorts with multiple measurements at different time points, the effect size between constructs at baseline were recorded.

Random effect models weighted by sample size were used in the meta-analysis to calculate the overall effect sizes. A forest plot was generated as a graphical representation of the meta-analysis. The presence of publication bias was assessed by funnel plot. (Egger, Smith, Schneider, & Minder, 1997).

Tests for homogeneity of effects. The significance of heterogeneity (Q), extent of heterogeneity (I^2), and percentage of variance due to artifact (or the '75%' rule') (Hunter & Schmidt, 1990, 2004) were examined. The I^2 statistic provides an indication of the extent to which results are consistent across trials. Values of I^2 equal to .25, .50, and .75 were considered low, moderate, and high, respectively (Higgins, Thompson, Deeks, & Altman, 2003). Q statistic is the weighted sum of squared difference between individual study effects and pooled effect across studies. A significant Q statistic suggests heterogeneity of effects. For the '75% rule' as recommended by Hunter and Schmidt (1990, 2004), effect sizes were considered homogenous if 75% or more of the total variances are attributed to corrected artifacts (i.e., sampling and measurement errors). In cases where the homogeneity rule was not met, moderator analyses were conducted.

Path analysis. Based on the meta-analyzed correlations, path analyses using Mplus (Muthén & Muthén, 2008) were conducted to test the TPB portion of RAA (final model is shown in Figure 3.2). As in previous meta-analyses that have adopted follow-up path analyses (Ng et al., 2012; Viswesvaran & Ones, 1995) , the harmonic mean of the sample sizes underpinning each effect size represented in the path models was used as the input sample size. Goodness-of-fit indices such as chi-square, the comparative fit index (CFI), the root mean square error of estimation (RMSEA) and standardized root mean square residual (SRMR) were used to assess model fit. Based on the recommendations of Hu and Bentler (1999), CFI values exceeding .95 indicates good model fit, whereas RMSEA should not surpass .08 and SRMR should not exceed 0.06.

Moderator analyses. Information such as mean age of the participants (elementary school-aged vs high school-aged), study population (North American vs rest of the world), study design (cross-sectional studies vs non-cross-sectional studies) , and method of PA measurement (self-reported vs objective measurement using accelerometers and pedometers) were coded to allow moderator analyses to be conducted for heterogeneity of effect sizes. Moderator analyses involved additional series of meta-analyses on the same set of correlations carried out separately across the levels of the moderator. If the confidence intervals of the separate effect sizes do not overlap, the variable were regarded as a moderator (Hwang & Schmidt, 2011).

The study protocol has submitted to Indiana University Human Subjects Office for record. The study was exempted from human subjects review by the Office of Research Compliance, Indiana University, as it is a meta-analysis of published data and did not contribute human subject research.

Results

Study selection. Study selection results are shown in Figure 3.1. From an initial pool of 866 non-duplicate records, screening of titles and abstracts led to 71 full-text articles read. From these, 36 articles with various study types met the inclusion criteria and were meta-analyzed.

Study characteristics. The summary of these studies, including first author's name, year of publication, study design, country, sample size, age range, constructs measured and type of PA measurement, is listed in Table 3.1. Publication dates ranged from 1990 to 2016. Fourteen studies were conducted in the North America (the US and Canada), fifteen in the rest of the

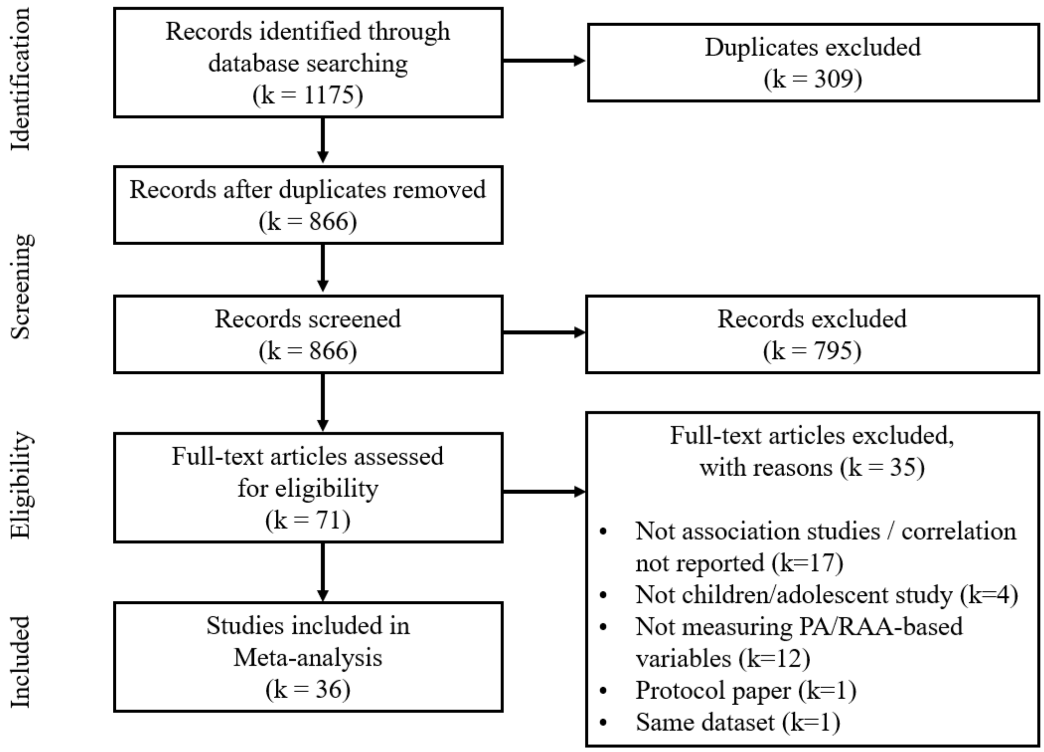

Figure 3.1. PRISMA 2009 flow diagram for included studies, depicting flow of information through the phases of Study 1.

Table 3.1

Summary of Meta-Analyzed Studies in Study 1

Article	Country	Ethnicity / Characteristics	Study design	n (M/F)	Age	TPB/RAA measure	PA Measure
Araujo-Soares et al. (2015)	Scotland		Prospective	177 (91/86)	4-6 Grade 1-2	INT, ATT, SN, PBC	MVPA (Accelerometer)
Armitage et al. (2010)	England	Low SES	Experimental	77 (39/38)	8.06±1.63 6-10	INT, ATT SN, PBC	PA (Self-report questionnaire)
Baker et al. (2003)	US	92.2%C	Longitudinal	279 (82/197)	15.1±0.9(M) 14.8±0.4(F)	INT, ATT SN	PA (Modified GLTEQ)
Barkoukis et al. (2010)	Greece		Prospective	274 (132/137)	16.89±0.65	INT, ATT SN, PBC	VPA (Modified GLTEQ)
Belanger-gravel et al. (2010)	Canada		Cross-sectional	313 (152/161)	10.4±0.5 Grade 5	INT, ATT SN, PBC	PA (Self-report questionnaire)
Cao et al. (2013)	China		Prospective	534 (256/278)	13.95±1.67 Grade 7-12	INT	MVPA (IPAQ)
Christodoulos et al. (2006)	Greece		Experimental	29 (18/11)	10-12.5 Grade 6	INT, ATT	MVPA (Physical Activity Recall Questionnaire)
Craig et al. (1996)	US	44%C, 20%AA, 12%H, 8%A	Cross-sectional	305 (162/143)	G5: 10.8±0.5 G8: 13.9±0.5	INT, ATT SN, PBC	/
Dishman et al. (2006)	US	56.9%AA, 40.5C	Longitudinal	862 (0M/862)	G9: 14.6±0.6 G12:	INT, ATT SN, PBC,	PA (3DPAR)
Foley et al. (2008)	New Zealand	52%C, 11%PI 11%A	Cross-sectional	638 (348/290)	11.59±0.88 11-13	INT, ATT SN, PBC	PA (PAQ-C)
Gonzales-Cutre et al. (2014)	Spain	Caucasian	Prospective	300 (200/200)	13.9±1.33 12-18	INT, ATT SN, PBC	MVPA (GLTEQ)
Guinn et al. (2006)	US	Mexican	Cross-sectional	401 216/185)	10-15	INT	MVPA (Self-report questionnaire)
Hamilton et al. (2016)	Australia	English-speaking background	Prospective	226 (89/137)	13.5±0.59 12-16	INT, SE	VPA (1DPAR)

Article	Country	Ethnicity / Characteristics	Study design	N (M/F)	Age	TPB/RAA measure	PA Measure
Hamilton et al. (2008)	Australia	Caucasian	Cross-sectional	423 (172/251)	13.47±0.56 13-14	INT, ATT SN, PBC,	MVPA (# of days)
Hashim et al. (2014)	Malaysia	Malay	Cross-sectional	320 (141/179)	10.46±0.52 10-11	INT, ATT, SN, PBC	MVPA (PAQ-C)
Keats et al. (2007)	Canada		Retrospective	320 (195/125)	17.37±1.29 15-20	INT, ATT SN, PBC,	MVPA (GLTEQ)
Kerner et al. (2003)	US	54C, 50H, 21AA, 4A	Cross-sectional	129 (0/129)	14.8±1.1	INT, ATT SN, PBC	PA (21-day PA diary)
Martin et al. (2008)	US	Arab American	Cross-sectional	348 (179/169)	12.24±0.94 10-14	INT, ATT SN, PBC	MVPA (GLTEQ)
Martin et al. (2007)	US	Mexican	Cross-sectional	475 (233/242)	10.4±0.57 9-12	INT, ATT SN, PBC	MVPA (GLTEQ)
Motl et al. (2002)	US	49.9%AA 45.8%C	Experimental	1797 (0/1797)	13.57±0.63	INT, ATT SN, PBC,	MPA, VPA (3DPAR)
Murnaghan et al. (2010)	Canada	79.5%C	Prospective	287 (141/146)	12-16	INT, ATT SN, PBC	MVPA (Self-report questionnaire)
Plotnikoff et al. (2013)	Canada	Overweight / obese	Cross-sectional	560 (308/252)	13.7±1.5 G7-10	INT, ATT SN, PBC	PA (PAQ-C)
Raudsepp et al. (2010)	Estonia		Longitudinal	236 (0/236)	12.7±0.5 12-13	INT, ATT SN, PBC	PA (3DPAR)
Reynolds et al. (1990)	US		Longitudinal	743 (388/355)	15(median) 14-16, G10	INT, SE	PA (Self-report questionnaire)
Rhodes et al. (2006)	Canada	230A, 134C	Longitudinal	364 (178/186)	11.22±0.59 9-11, G5	INT, ATT SN, PBC	PA (PAQ-C)
Roberts et al. (2010)	New Zealand	78%PI, 18%Maori	Cross-sectional	72 (34/38)	16.92±0.66 16-19	INT, ATT SN, PBC,	PA (Pedometer, PAQ-A)

Article	Country	Ethnicity / Characteristics	Study design	N	Age	TPB/RAA measure	PA Measure
Sallis et al. (1999)	US	82%Caucasian, 12%Asian/PI	Prospective	732 (362/370)	9.54±0.55 Grade 4	INT, ATT	PA (Accelerometer)
Tessier et al. (2015)	France		Experimental	116 (42/74)	Mean=15.07 High school	INT, ATT SN, PBC	PA (IPAQ)
Thomas et al. (2014)	UK	Caucasian	Longitudinal	621 (320/301)	9.8±0.89 9-11	INT, ATT SN, PBC	MVPA (PAQ-C)
Trost et al. (2002a)	US	55.9%AA	Cross-sectional	213 (102/111)	11.4±0.6	INT, ATT SN, PBC	MVPA (Accelerometer)
Trost et al. (2002b)	US	1114AA, 1030C	Cross-sectional	2144 (0/2144)	13.7±0.7	INT, ATT SN, PBC,	MVPA (3DPAR)
Tsorbatzoudis et al. (2005)	Greece		Experimental	366 (174/188)	14.2±0.69	INT, ATT SN, PBC	Exercise habits (Self-report questionnaire)
Wallhead et al. (2014)	US	70-80%C	Experimental	568 (258/310)	14.75±0.48	INT	MVPA (GLTEQ)
Wallhead et al. (2010)	US	130C, 56AI, 6 other	Prospective	192 (97/95)	10.9 9-14	INT, ATT SN, PBC	Lunch-recess sports participation (Pedometer)
Wang et al. (2016)	China	Chinese	Cross-sectional	488 (279/209)	13.91±0.96 12-16	INT, ATT SN, PBC	MVPA (GLTEQ)
Wang et al. (2015)	China	Chinese	Cross-sectional	353 (180/173)	11.26±0.98 9-13	INT, ATT SN, PBC	MVPA (Accelerometer)

Note. INT: Intention; ATT: Attitude; SN: Subjective norms; PBC: Perceived behavioral control; SE: Self-efficacy; PA: Physical activity; VPA: Vigorous physical activity; MVPA: Moderate-to-vigorous physical activity; SES: Socioeconomic status. For ethnicities, C: Caucasian; AA: African American; H: Hispanic; A: Asian; PA: Pacific Islander.

world. Six studies employed an experimental design, other studies included longitudinal or cross-sectional design.

The number of participants in the included studies ranged from n=29 (Christodoulos, 2006) to n=2,144 (Trost, 2002b). Four studies directly compared intention with PA by sex, as well as 5 studies that included female participants only.

Outcome measures. As shown in Table 3.1, four studies used accelerometers to measure the time spent in MVPA (Araujo-Soares, 2015; Sallis, 1999; Trost 2002a; Wang, 2015). Pedometer were employed in two studies (Roberts, 2010; Wallhead, 2010). Twenty nine studies measured PA via self-reported measures. One study did not measure physical activity (Craig, 1996).

Synthesis. ***Intention to physical activity.*** The correlations between constructs are shown in Table 3.2. Thirty-five samples were available to evaluate physical activity in the meta-analysis for a total of 16,060 participants. The pooled correlation was 0.343 ($p < 0.01$), with an observed variance of 0.027 and a sampling error of 0.003. The 95% CI of population r was 0.288 to 0.399. The overall combined result derived from pooling the individual studies is shown in the forest plot (Figure 3.3). The black squares represent the correlations of the individual studies, and the horizontal lines represent their 95% confidence intervals (CI). The area of the black squares reflects the weight each trial contributes in the meta-analysis. The overall treatment effect from the meta-analysis and its CI is at the bottom and represented as a diamond. The center of the diamond represents the combined treatment effect (0.33), and the horizontal tips represent the 95% CI (0.28 to 0.39). The asymmetric shape in funnel plot (Figure 3.4) shows that heterogeneity or reporting bias could be present.

Attitude to intention. Twenty-nine samples were available to evaluate attitude in the meta-analysis for a total of 12857 participants. The pooled correlation was 0.555 ($p < 0.01$), with an observed variance of 0.017 and a sampling error of 0.005. The 95% CI of population r was 0.505 to 0.606.

Subjective norms (SN) to intention. Twenty-seven samples were available to evaluate SN in the meta-analysis for a total of 12736 participants. The pooled correlation was 0.436 ($p < 0.01$), with an observed variance of 0.023 and a sampling error of 0.003. The 95% CI of population r was 0.373 to 0.499.

Perceived behavioral control (PBC) / self-efficacy (SE) to intention. Twenty-nine samples were available to evaluate PBC/SE in the meta-analysis for a total of 13139 participants. The pooled correlation was 0.586 ($p < 0.01$), with an observed variance of 0.022 and a sampling error of 0.004. The 95% CI of population r was 0.525 to 0.648.

Path analysis. The test of model fit for RAA is shown on Figure 3.2. Though significant Chi-square test value was found (χ^2_7=9725.403, p<0.01), all other indices (CFI = 0.994, RMSEA = 0.048, SRMR = 0.015) suggested that RAA is a good-fitting model. All model paths were significant.

Moderator analyses. Based on our above analyses of observed variances and sample errors, the Hunter and Schmidt (2004) 75% homogeneity rule were not met. The forest plot (Figure 3.3) and high I^2 values (Table 3.2) also suggested the possible presence of heterogeneity. Moderator analyses were therefore conducted in order to investigate if effect modification exist among subgroups.

Table 3.2

Correlation between constructs in Study 1

	PA	Intention	Attitude	Subjective Norms	PBC / Self-efficacy
PA	-	k = 35 N = 16060 $\rho = 0.343$ (0.288-0.399) $p < 0.01$ Q = 1176.97*** $I^2 = 96.6\%$ 75%=10.59	k = 28 N = 12839 $\rho = 0.246$ (0.194-0.298) $p < 0.01$ Q = 241.89*** $I^2 = 88.8\%$	k = 25 N = 11527 $\rho = 0.230$ (0.183-0.277) $p < 0.01$ Q=149.95*** $I^2 = 84.0\%$	k = 26 N = 11804 $\rho = 0.304$ (0.244-0.364) $p < 0.01$ Q=358.44*** $I^2 = 93.0\%$
Intention		-	k = 29 N = 12857 $\rho = 0.555$ (0.505-0.606) $p < 0.01$ Q = 403.51*** $I^2 = 92.1\%$ 75%=31.23	k = 2 N = 12736 $\rho = 0.436$ (0.373-0.499) $p < 0.01$ Q=518.09*** $I^2 = 94.4\%$ 75%=9.21%	k = 29 N = 16472 $\rho = 0.586$ (0.525-0.648) $p < 0.01$ Q=781.79*** $I^2 = 96.0\%$ 75%=17.87%
Attitude			-	k = 25 N = 11612 $\rho = 0.446$ (0.374-0.518) $p < 0.01$ Q=535.80*** $I^2 = 95.5\%$	k = 26 N = 11804 $\rho = 0.577$ (0.531-0.622) $p < 0.01$ Q=258.15*** $I^2 = 90.3\%$
Subjective Norms				-	k = 25 N = 11612 $\rho = 0.407$ (0.334-0.479) $p < 0.01$ Q=467.66*** $I^2 = 94.9\%$
PBC / Self-efficacy					-

Note. PA = physical activity; PBC = perceived behavioral control; N = total number of participants; ρ = effect size (95% confidence intervals); k = number of studies; Q = significance of heterogeneity; I^2 = extent of heterogeneity.

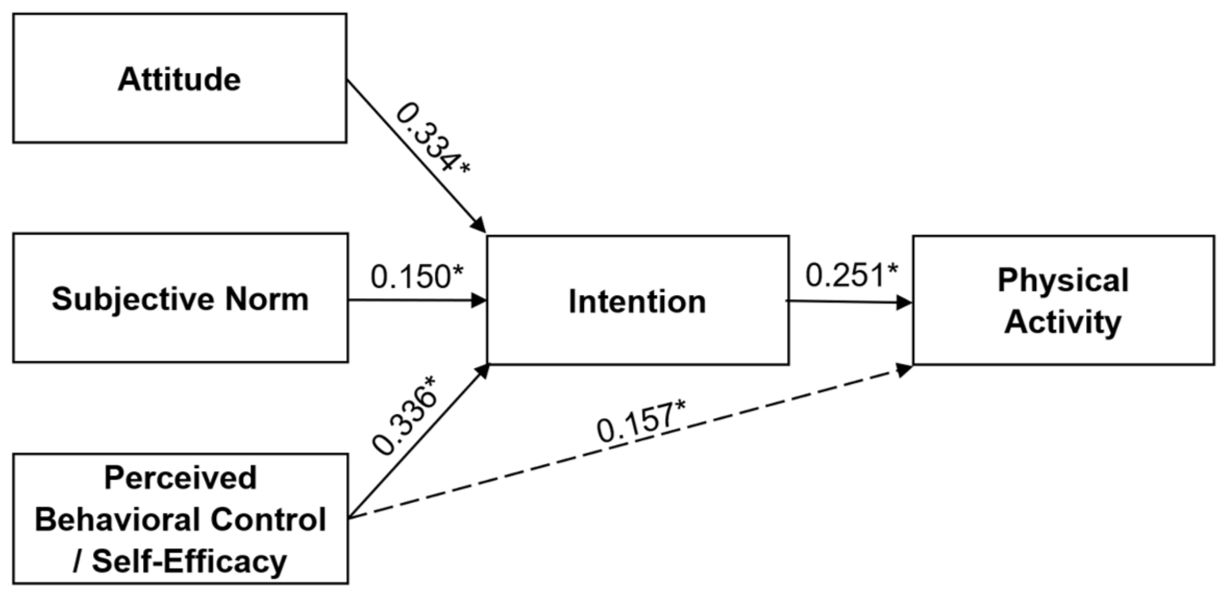

Figure 3.2. Path diagram of attitude, subjective norms, self-efficacy, intention and physical activity based on the result of meta-analysis. All paths were significant, $p < 0.05$.

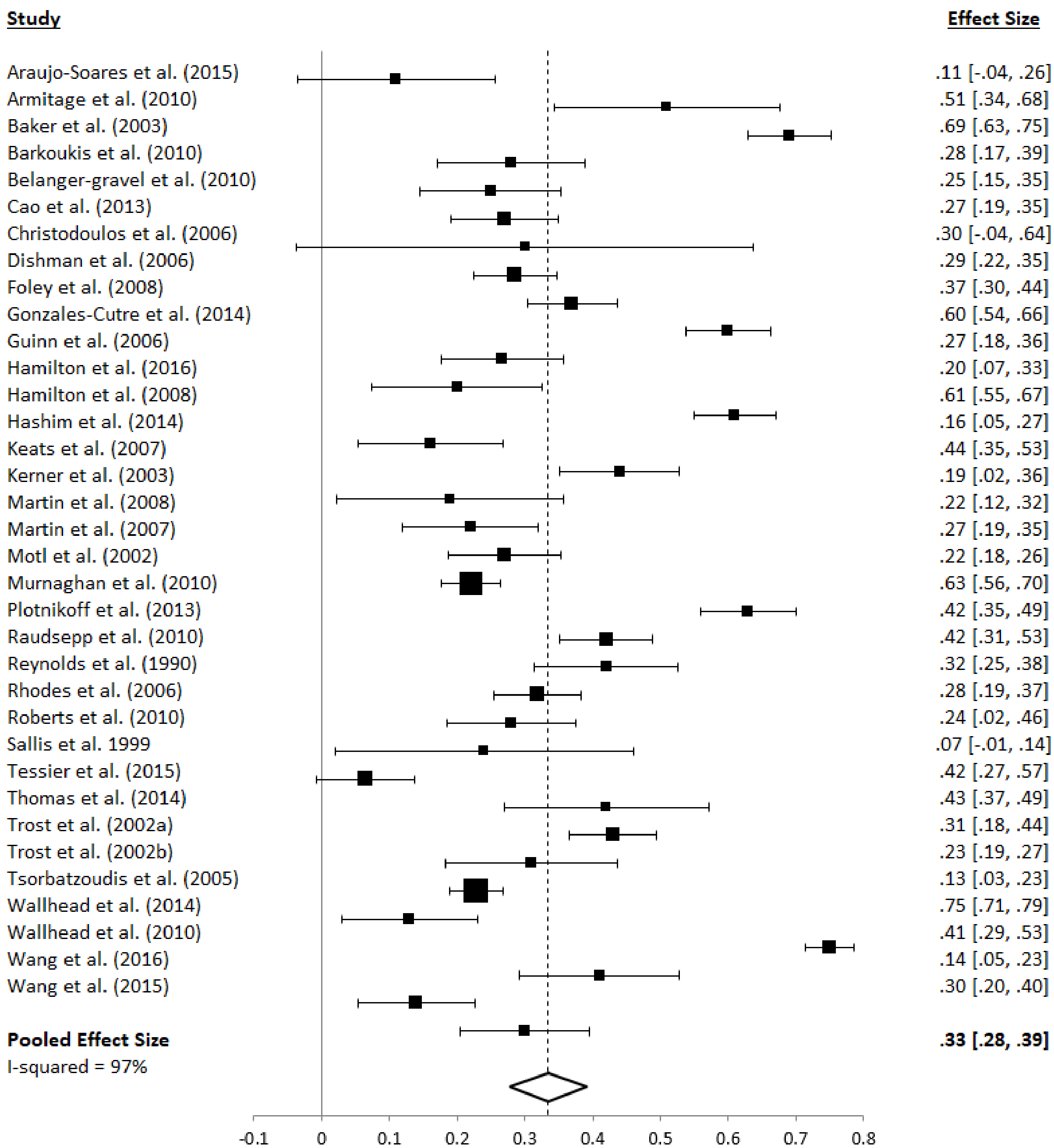

Figure 3.3. Forest plot showing the correlations between PA and intention found in all included studies.

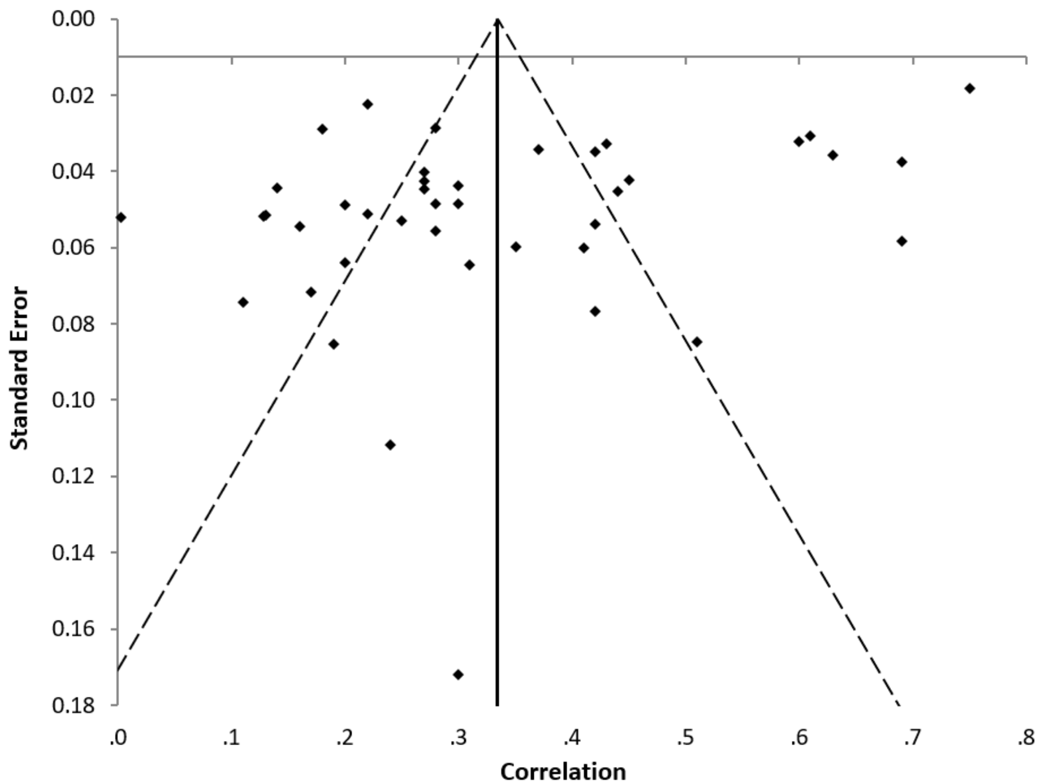

Figure 3.4. Funnel plot of intention and physical activity in children. (The pooled correlation is shown as a dark line.)

Table 3.3

Moderator analysis of the effect of RAA-based variables between results from North American children and adolescents and that from the rest of the World

Relationship between constructs	Pooled Correlation (r)	
	Studies from North American children and adolescents	Studies from the rest of the world
Attitude - Intention	0.524 (k = 14) (95% CI = 0.459-0.590)	0.597 (k = 15) (95% CI = 0.517-0.676)
Subjective Norms - Intention	0.372* (k = 14) (95% CI = 0.299-0.446)	0.562* (k = 13) (95% CI = 0.464-0.659).
PBC / Self-efficacy - Intention	0.510* (k = 14) (95% CI = 0.436-0.584)	0.714* (k = 15) (95% CI = 0.630-0.799)

Note. Statistically significant, $p < 0.05$.

Region of study. As shown in Table 3.3, for SN-intention relationship, studies involved North American children and adolescents (k=14) found a pooled correlation of 0.372 (95% CI = 0.299-0.446), while studies from the rest of the world (k=13) had a pooled correlation of 0.562 (95% CI = 0.464-0.659). Region of study was a moderator of SN-intention relationship. For PBC/SE, studies with North American children and adolescents (k=14) found a pooled correlation of 0.510 (95% CI = 0.436-0.584), while the rest (k=15) had a pooled correlation of 0.714 (95% CI = 0.630-0.799). Region of study was a moderator of PBC/SE-intention relationship. For attitude, studies with North American children and adolescents (k=14) found a pooled correlation of 0.524 (95% CI = 0.459-0.590). For studies from the rest of the world (k=15), the pooled correlation was 0.597 (95% CI = 0.517-0.676). Region of study was not a moderator of attitude-intention relationship.

Sex. Four studies directly compared intention with PA by sex, as well as five studies that included female only. The pooled correlation of MVPA and attitude for girls only was 0.26. The 95% CI of population r was 0.189 to 0.339. For the rest of the studies, the pooled correlation of MVPA and attitude was 0.393. The 95% CI was 0.323 to 0.463. For attitude-intention, boys (k=1) had a pooled correlation of 0.562; Girls (k=6) had a pooled correlation of 0.493 (95% CI = 0.405-0.581); the rest of the studies with both boys and girls (k=23) had a pooled correlation of 0.578 (95% CI = 0.514-0.643). For norms-intention, girls (k=5) had a pooled correlation of 0.351 (95%CI = 0.286-0.415), while the rest (k=22) had a pooled correlation of r=0.490 (95%CI = 0.406-0.575). For PBC/SE-intention, girls (k=5) had a pooled correlation of 0.541 (95%CI = 0.424-0.648), and mixed (k=24) had a pooled correlation of 0.607 (95%CI = 0.531-0.683). To conclude, sex was not a moderator of the above relationships.

Age. For attitude, 11 studies were done with elementary school students, the pooled correlation was 0.565 (95%CI = 0.453-0.677). Among high school students (k=19), the summary was 0.545 (95%CI = 0.490-0.601). For norms, 10 studies were done with elementary school students, the pooled correlation was 0.448 (95%CI = 0.309-0.587). Among high school students (k=18), the summary was 0.427 (95%CI = 0.357-0.497). For PBC/SE, 13 studies were done with elementary school students, the pooled correlation was 0.547 (95%CI =0.445-0.650). Among high school students (k=17), the pooled correlation was 0.596 (95%CI = 0.524-0.668). These indicate that age / school was not a moderator of these relationships.

Study design. For studies with PA measurement, 14 of them were cross-sectional studies. The pooled correlation between intention and PA was 0.307 (95%CI = 0.244-0.369). For other study designs (k=22), the pooled correlation was 0.366 (95%CI = 0.287-0.446). For attitude-intention relationship, cross-sectional studies (k=14) had a pooled correlation of 0.498 (95%CI = 0.421-0.575). Other study designs (k=15) got a pooled correlation of 0.620 (95%CI = 0.564-0.677). For norms-intention relationship, cross-sectional studies (k=14) had a pooled correlation of 0.413 (95%CI = 0.317-0.509). Other study designs (k=13) got a pooled correlation of 0.464 (95%CI = 0.386-0.542). For PBC/SE-intention relationship, cross-sectional studies (k=14) had a pooled correlation of 0.504 (95%CI = 0.422-0.585). Other study designs (k=15) got a pooled correlation of 0.679 (95%CI = 0.604-0.753). Study design was a moderator between PBC/SE and intention, but not for other relationships.

Mode of PA measurement. Four studies measured PA objectively, either using accelerometers or pedometers. The pooled correlation was 0.289 (95% CI = 0.201-0.377). Thirty-two studies measured PA via self-reported measures. The pooled correlation was 0.351

(95% CI = 0.294-0.409). Mode of PA measurement was not a moderator of intention-PA relationship.

Discussion

This study provides a summary of current scientific findings about the association between RAA-based variables and PA in children and adolescents worldwide. The primary objective of this study was to evaluate the association between PA and intention to engage in PA among children and adolescents (Specific Aim 1). Although a review previously conducted (Van Der Horst, Paw, Twisk, & Van Mechelen, 2007) concluded that the association between PA and intention was "inconclusive", our results support that intention is a significant correlate of PA in children. The pooled correlation was 0.343, which was a medium effect based on Cohen's (1988) interpretation. We also aimed to examine the effect size between attitude, subjective norms, perceived behavioral control / self-efficacy and intention to engage in PA among children and adolescents (Specific Aim 2). Large effects were found between attitude and intention (r = 0.591), and between self-efficacy (SE) / perceived behavioral control (PBC) and intention (r = 0.586). The effect between subjective norms and intention was medium (r = 0.436). The direct effect between self-efficacy / PBC and physical activity was medium (r = 0.304). Along with the results in the path analysis, our meta-analysis provides support for the Reasoned Action Approach (RAA) which has a medium to high effect in explaining PA in children and adolescents worldwide. It also demonstrates the significance of intrapersonal determinants, as the base level of the social ecological model, in promoting PA among children and adolescents.

The study also aimed to examine the effect modifications of geographical region of study and ethnicity between RAA-based variables and PA (Specific Aim 3). Based on the results of the moderator analysis, while age and sex did not modify the relationships between attitude, subjective norms, self-efficacy / perceived behavioral control and intention, geographical region of study was found to be an effect modifier of SN-intention as well as PBC/SE-intention relationship. Compared to studies conducted in North America, the pooled correlation of SN-intention and PBC/SE-intention in studies conducted in the rest of the world was larger. Relationship between SN and intention is stronger for studies conducted in the rest of the world. Similar result was found for PBC/SE-intention relationship. It indicates that SN and PBC/SE play a more important role in children of the rest of the world, compared to US/Canadian children. In other words, studies targeting the same intrapersonal construct(s) would have different magnitude of effect on physical activity intention in children and adolescents in different countries. Such effect modification of geographical region of study indicates that there are underlying differences between countries, such as culture and ethnicity, which might play a significant role in modifying the intrapersonal determinants of physical activity in children and adolescents.

The results of path analysis support our hypothesis that RAA is an appropriate model in explaining PA in children, but the magnitudes of some paths were smaller than the original pooled correlations. It might be due to the common variances shared by the variables.

In our initial study plan, we intended to conduct a meta-analysis on all the constructs involved in RAA, including other proximal determinants, such as behavioral beliefs, evaluation of consequences, normative beliefs, motivation to comply, control beliefs and perceived power. After initial literature search, however, we found it not possible as there were only very few studies which have included these upstream determinants in studying PA behavior. We also planned that only objectively measured PA would be used to investigate the relationship of PA with other variables. There were, however, limited number of objectively measured PA studies available. Self-reported data were then included, and methods of PA measurement was hypothesized as a prospective effect modifier. Some studies suggested that self-reported data might overestimate the accelerometer-measured PA level. (Dyrstad, Hansen, Holme, & Anderssen, 2014) But in our moderator analysis, we found that mode of PA measurement was not an effect modifier.

There were plans to adopt accelerometers to measure physical activity in large-scale epidemiological studies. (I.-M. Lee & Shiroma, 2014) However, methods used to process and score accelerometer data for youth are so diverse that no consistent cutoff point is established. (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013) A review done by Pedisic and colleagues (2015) also supported this point, and stated that there are still several issues associated with the validity of accelerometer-based estimates. They concluded it may be still premature to adopt accelerometers widely for large-scale PA surveillance systems.

One of the limitations of our study is that studies published in languages other than English were not included. An extensive search in English language databases have been conducted to obtain a robust search of journals. Another limitation is the limited number of studies available for analysis. Cognitive abilities of children to self-report psychosocial variables are limited, few studies have been done to assess these variables on them (Sallis, Prochaska, & Taylor, 2000). Long questionnaires with lots of words should be avoided wherever possible for studies in children. Choices with graphical representation to assist understanding would be a possible alternative. In terms of study methodology, a follow-up meta-regression might be conducted to further investigate the relationship between moderators. The current Hunter and Schmidt method, however, corrects for reliability and is commonly used in other meta-analyses

(Hagger & Chatzisarantis, 2009; Mayorga-Vega, Aguilar-Soto, & Viciana, 2015; J. Y. Y. Ng et al., 2012; Wolden, Hill, & Farquhar Voorhees, 2019).

Despite the widespread use of RAA in guiding health promotion research and interventions, little evidence exists on magnitude of the role RAA-based variables plays on PA among children and adolescents of various population groups. This study has filled this gap of knowledge. The medium to large effects we found between RAA-based variables and PA provide empirical evidence that these intrapersonal level factors in RAA (i.e. intention, attitude, SN and SE/PBC) are significant correlates of PA in children and adolescents. In addition, effect modification of geographical region of study was found in SN-intention and PBC/SE-intention relationship. These suggest that future PA promotion programs and interventions in children and adolescents should apply methods targeting specific intrapersonal construct(s) based on geographical region of study or study location, along with other characteristics of the target group or population.

CHAPTER 4:

CORRELATES OF OBESITY IN ADOLESCENTS: A MULTILEVEL ANALYSIS OF HONG KONG COMMUNITY FITNESS SURVEY

Introduction

As mentioned in Chapter 2, obesity is an epidemic among children and adolescents in many countries. A recent systematic analysis of 1,769 studies (Ng et al., 2014) found that the prevalence of childhood overweight and obesity combined has risen by 47.1% between 1980 and 2013 globally. The study found that the prevalence of overweight and obesity is rising among children and adolescents in developed countries, increasing from 16.9% in 1980 to 23.8% in 2013 for boys and 16.2% to 22.6% in girls. They also found an increase in prevalence in developing countries at these ages since 1980, with 12.9% of boys and 13.4% of girls being either overweight or obese in 2013 compared to 8.1% of boys and 8.4% of girls in 1980. In China, the prevalence of obesity in Chinese children (standardized by the 1985 Chinese national survey data), based on data of Chinese National Survey on Students' Constitution and Health, increased rapidly from 0.1% in 1985 to 5.0% in 2010 (Song et al., 2015). Data from these studies suggested that the gradual decrease of urban–rural disparity would cause a growing problem in childhood obesity in China. A similar pattern has also been observed in Hong Kong (see Figure 4.1). Yeung and Hui (2007) summarized weight and height data from nationwide school surveys conducted in Hong Kong from 2001 to 2006 (n=30845; 15614 boys and 15231 girls; aged 3-18 years) and compared to the 1993 Hong Kong Growth Survey conducted by the Hong Kong Department of Health. They found that childhood obesity increased from 11.3% to 22.5% for boys, and from 8.9% to 16.8% for girls, respectively. These percentages, however, were based on, or standardized by, the local growth charts produced from the 1993 Hong Kong Growth

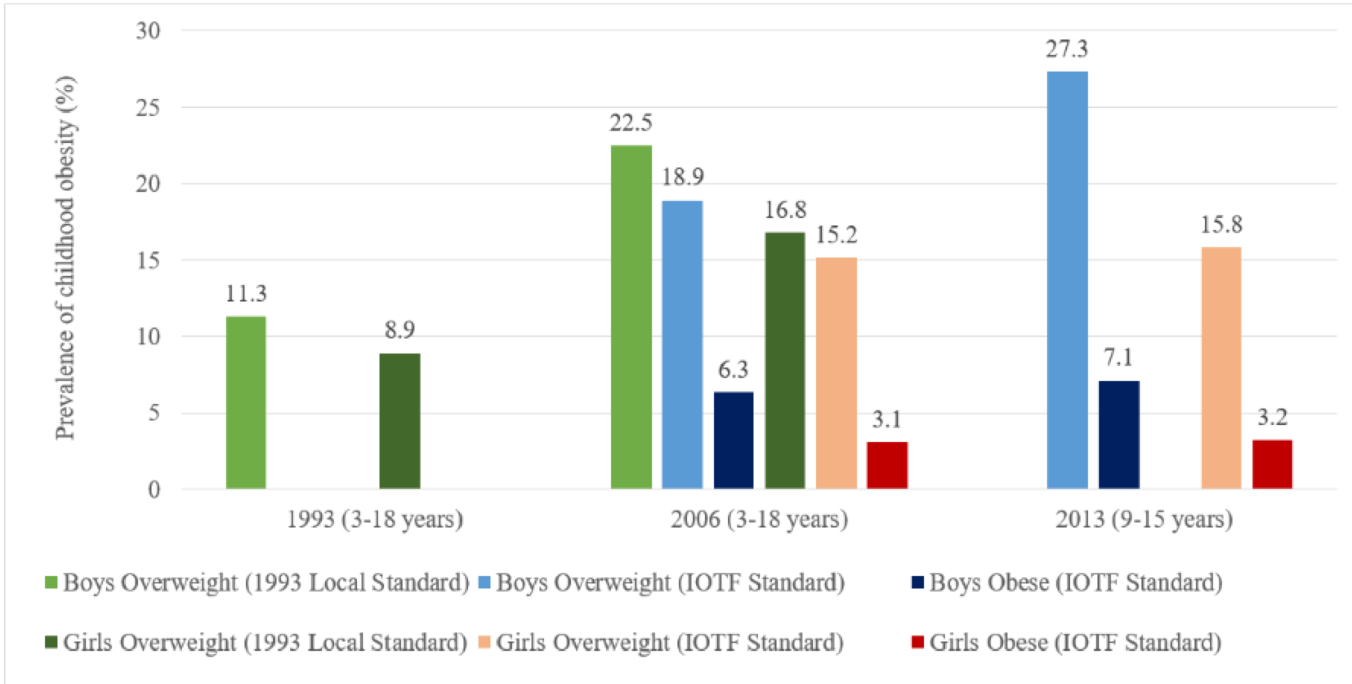

Figure 4.1. Prevalence of childhood obesity of Hong Kong in 1993, 2006 and 2013. Source: Hong Kong Department of Health (1993); Yeung & Hui (2007); and Lee, Lee, Sze, & Chien (2017). Only 1993 local standard (or definition) of childhood overweight (i.e. 120% weight-for-weight of local growth charts) was presented for 1993 data, as International Obesity Taskforce (IOTF) childhood overweight and obesity cutoff points were not established until year of 2000. IOTF standards for overweight and obesity were applied to define childhood obesity in 2006 and 2013 data.

Survey and were unable to compare to the prevalence of other countries. The authors advocates the application of the International Obesity Taskforce (IOTF) reference standards (cutoff points) to define childhood obesity, produced by Cole and colleagues (2000), so cross-country or region comparison could be made. They were one of the first research teams in Hong Kong to apply the IOTF standards (Yeung & Hui, 2008). Since then, the IOTF standards have been applied in other recent local childhood obesity studies (Lee, Lee, Sze, & Chien, 2017; Wang, Gao, & Lau, 2017).

The city of Hong Kong is an ideal location to study the geographical effects of obesity. Although the total area of Hong Kong is merely 2,754 km^2, there is a huge difference in population density (see Figure 4.2 and Appendix A), demographic data and pollution level (see Appendix B) between districts. Apart from that, the blending of westernization and Chinese culture makes Hong Kong possibly an ideal site of predicting the future development of obesity in other developing cities in mainland China.

The current study, therefore, aimed to examine putative individual-level as well as district-level determinants of obesity among adolescents in Hong Kong, one of the metropolitan cities in southeast China, through population survey and census data. Multilevel approach was incorporated to take both within- and between- district level variability into account. We hypothesized that individual-level factors (student's MVPA, intention to exercise, sex, time spent doing homework, screen time, sleep quality and family exercise participation), and district-level factors (air pollution levels, population density and district mean income) are predictors of body fat percentage of adolescents in Hong Kong.

Methodology

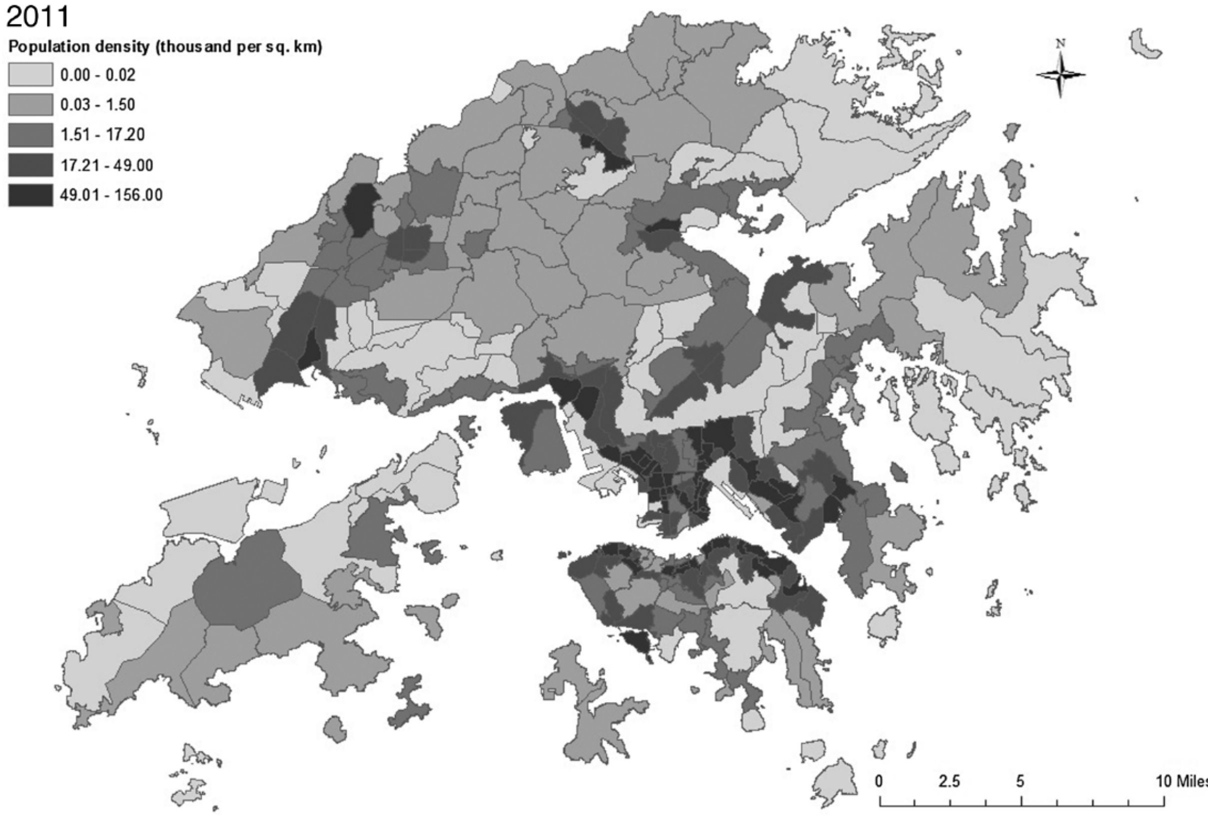

Figure 4.2

Population density of Hong Kong by districts. Adopted from Yao and Loo (2016).

Data. Data was obtained from the Second Community Fitness Survey in Hong Kong. It was a citywide survey implemented every five years by the Hong Kong Government, and was steered by the Community Sports Committee of Hong Kong, and coordinated by the Leisure and Cultural Services Department (LCSD) of the Hong Kong Government in 2010-2011 (The Chinese University of Hong Kong, 2012). It included a series of standardized physical fitness tests and questionnaire survey adopted by the General Administration of Sport, China. Targeted participants of the Survey were Hong Kong citizens aged 3–69. Data from adolescents aged 13–19 were extracted and analyzed in our study. The original study protocol was approved by the respective research committee designated by the Hong Kong Government. All participants signed informed consents at the time of participation. Data has been de-identified and data access has been approved by the principal investigator of the Survey and LCSD. This study was exempted from human subjects review by the Indiana University Office of Research Compliance.

Stratified random sampling was used to select one high school each from each district of Hong Kong (18 in total). In Hong Kong, a district is a municipality with its own administrative council (Figure 4.2). A total of 2,805 student participants aged between 13 and 19 years were recruited and 2,517 sets of completed questionnaires with physical fitness data were successfully collected (89.73%). One class from each grade was randomly selected to participate in the study. There was an average of 139 students per district in the sample (Table 4.1).

Questionnaire. The questionnaire was adopted from the “Hong Kong Community Fitness Survey” implemented by the LCSD every five years. The questionnaire had two sections with a total of 43 items. The first section enquired on the PA participation using the International Physical Activity Questionnaire Short version (IPAQ-Short), which has been used extensively in

Table 4.1

Number of participants completed both the questionnaire and physical fitness test in each of the 18 districts in Hong Kong

District	**N**
Sham Shui Po	119
Kwun Tong	152
Tuen Mun	141
Yuen Long	166
Sai Kung	146
Tsuen Wan	149
Wan Chai	95
Yau Tsim Mong	89
Eastern	142
Tai Po	116
Kowloon City	131
North	141
Central / Western	117
Wong Tai Sin	150
Twai Tsing	128
Southern	235
Shatin	152
Islands	148
Total	**2517**

many international studies (Craig et al., 2003; P. H. Lee et al., 2011). The IPAQ-Short derives estimation on MVPA in terms of minutes/week. Question items in the second section were extracted from the China National Fitness Surveillance Project (China Physical Fitness Surveillance Center, 2005). These questions included attitude and preference of PA participation, reasons for engaging and not engaging in PA, other lifestyle information (such as amount of time spent watching TV and/or computer, working on homework, sleep hours, awareness of exercise promotion launched by the government), and other demographic information such as parental education, parents' PA participation, profession, and family income. The questionnaire was distributed to students during Physical Education classes on one of the fitness testing days, and the students were guided in answering by a trained research assistant. Details can be found in the website: http://www.ipaq.ki.se/ipaq.htm. Validity and reliability of IPAQ-Short can be found in another source (Macfarlane et al., 2007).

Physical fitness tests. Field physical fitness tests including body weight and height, skinfold thickness, and the 15-meter PACER run test, were administered to the students in the schools during Physical Education classes. All fitness tests were administered by certified fitness testers recruited from the Physical Fitness Association of Hong Kong. Body weight and height were recorded in kilograms and centimeters, respectively. Result of 15-meter PACER run test was expressed in a score that was equivalent to number of laps completed by the participant. Participants' body fat percentages were calculated using ethnic-specific equations suggested by previous literature (Yeung & Hui, 2010) based on participants' skinfold thickness and age, as discussed in Chapter 2 (Table 4.2).

Ethnic-specific skinfold equations in estimating children and adolescents' body composition suggested by Yeung & Hui (2010) based on participants' skinfold thickness and age

Model	Gender	Intercept	β	r	R^2	SE
Best Models						
$(\sum 3SKF)^2 + \sum 3SKF$ + Height	Boys	22.091	-0.003	0.94	0.88	3.7
			0.76			
			-0.147			
$\sum 2SKF$ + Height + Waist C	Girls	17.539	0.303	0.84	0.71	3.38
			0.516			
			-0.175			
Convenience Models						
Triceps + Age	Boys	14.405	1.479	0.9	0.81	4.67
			-0.856			
Triceps + Age	Girls	13.936	1.17	0.8	0.64	3.77
			-0.502			

Note. $\sum 2SKF$ = sum of triceps and calf skinfolds; $\sum 3SKF$ = sum of triceps, calf and suprailiac skinfolds; Waist C = waist circumference; β = regression slope; r = regression correlation; R^2 = R-square; SE = standard error.

Amount of participant's moderate to vigorous physical activity (MVPA) (in minutes per week) was computed by multiplying participant's number of days of doing MVPA per week by the average duration (in minutes) of MVPA per day. Participants' family income per month in Hong Kong Dollars was measured using a 10-point scale (1 = no income, 2 = ≤$4,999, 3 = $5,000-$9,999, 4 = $10,000-$19,999, 5 = $20,000-$29,999, 6 = $30,000-$39,999, 7 = $40,000-$49,999, 8 = $50,000-$59,999, 9 = $60,000-$99,999, 10 = ≥$100,000) (1US Dollar = 7.75HK Dollars). Student's time spent doing homework was measured by a five-point scale (1 = <30 minutes, 2 = 30-59 minutes, 3 = 60-119 minutes, 4 = 120-179 minutes, 5 = >180 minutes). Student's daily screen time was measured by a six-point scale (1 = <30 minutes, 2 = 30-59 minutes, 3 = 60-119 minutes, 4 = 120-179 minutes, 5 = 180-239 minutes, 6 = >240 minutes). Student's intention to engage in PA was measured by a three-point scale (1-3 scale, 1 = high, 2 = medium, 3 = low). Student's attitude towards PA was measured by a three-point scale (1 = high, 2 = medium, 3 = low). Sleep quality was measured by a five-point scale (1-5 scale, 1 = very bad, 2 = bad, 3 = normal, 4 = good, 5 = very good). Family exercise participation was measured by a four-point scale (1 = none, 2 = once per several months, 3 = 1-2 times per month, 4 = at least once per week).

Environmental variables. District population densities (in persons in km^2) were retrieved from data in 2011 Population Census, as shown in figure 4.2 and Appendix A. Yearly average of air pollution levels (PM_{10}, ozone, nitrogen dioxide, sulphur dioxide, in $\mu g/m^3$) of each district in 2010-2011 were retrieved from the online database of Environmental Protection Department.

Statistical Analysis. Descriptive statistics were computed. Age-adjusted correlations were used to determine the relationship between measured variables. Multilevel regression analyses were used to examine the effects of various predictor variables on student's body fat percentage. Multilevel analysis is a methodology for the analysis of data with complex patterns of variability, with a focus on nested sources of variability. Individual variables of sex, MVPA, attitude and intention to exercise, time spent doing homework, screen time, family income, sleep quality, Family exercise participation was entered to the models as first-level predictors. District level characteristics such as air pollution levels, population density and district mean family income were considered as second-level covariates. All the first-level predictor variables were grand mean centered.

District effects on student's body fat percentage were determined by calculating the intraclass (intra-district) correlation coefficient (ICC), defined as a ratio of between district variability divided by the sum of between district variability and within district variability.

The rationale and procedures of multilevel model building were explained in Snijders and Bosker (1999).

Null Model (empty model / intercept-only model) (Model 1). The model building process started by examining the null model with no predictors to assess between-district variation in student body fat percentage. This model addresses our research question regarding the variance in body composition attributable to students (level 1) and district (level 2). ICC was computed based on the data from the null model.

Level 1 (Individual Level) Model (Model 2). In the second model, individual level variables, such as sex, MVPA, intention, screen time, time spent on homework, sleep quality and family exercise participation were added to the previous null model. The formula is:

$$fat_{ij} = \beta_{0j} + \beta_{1j}(sex_{ij}) + \beta_{2j}(mvpa_{ij}) + \beta_{3j}(intention_{ij}) + \beta_{4j}(screen_{ij}) + \beta_{5j}(hw_{ij}) + \beta_{6j}(sleep_{ij}) + \beta_{7j}(family_{ij}) + R_{ij}$$

Where fat = Student's body fat percentage; sex = Student's sex; mvpa = Student's amount of MVPA; intention = Student's intention to engage in PA; hw = Student's daily time spent doing homework; screen = Student's daily screen time; sleep = sleep quality; family = family exercise participation.

L1 + L2 Model (Model 3). In the third model, district level variables, such as population density, district mean income, NO_2, O_3, PM_{10}, and SO_2, were added. The formulae are:

Level 1: $fat_{ij} = \beta_{0j} + \beta_{1j} (sex_{ij}) + \beta_{2j} (mvpa_{ij}) + \beta_{3j} (intention_{ij}) + \beta_{4j} (hw_{ij}) + \beta_{5j} (screen_{ij}) + \beta_{6j} (sleep_{ij}) + \beta_{7j} (family_{ij}) + R_{ij}$

Level 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{popden}_j) + \gamma_{02}(\text{income}_j) + \gamma_{03}(\text{PM10}_j) + \gamma_{04}(\text{O3}_j) + \gamma_{05}(NO2_j) + \gamma_{06}(\text{SO2}_j) + U_{0j}$$

Where popden = population density; income = Student's family income; PM10 = PM_{10} level; O3 = ozone level; NO2 = nitrogen dioxide level; SO2 = Sulphur dioxide level.

PACER Model (Model 4). In Model 4, MVPA in Model 3 was replaced by PACER to investigate whether cardiovascular fitness, represented by PACER test result, or MVPA was the better predictor of body fat percentage of our participants. The formulae are:

Level 1: $fat_{ij} = \beta_{0j} + \beta_{1j} (sex_{ij}) + \beta_{2j} (pacer_{ij}) + \beta_{3j} (intention_{ij}) + \beta_{4j} (hw_{ij}) + \beta_{5j} (screen_{ij}) + \beta_{6j} (sleep_{ij}) + \beta_{7j} (family_{ij}) + R_{ij}$

Level 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{popden}_j) + \gamma_{02}(\text{income}_j) + \gamma_{03}(\text{PM10}_j) + \gamma_{04}(\text{O3}_j) + \gamma_{05}(NO2_j) + \gamma_{06}(\text{SO2}_j) + U_{0j}$$

Where pacer: PACER test score.

SAS 9.3 (SAS Institute, 2011) were used for statistical analyses. All analyses were considered as significant in $\alpha \leq 0.05$ level.

Results

Descriptive statistics. The number of participants (n=2,517) completed both the questionnaire and physical fitness test in each of the 18 districts in Hong Kong ranged from 89 to 235 (Figure 4.1). The descriptive statistics of the physical and demographic characteristics of the participants are shown in Table 4.3. The average age of participants was 15.65 ± 1.71 years old. Boys had lower percent body fat and more MVPA. The mean percent body fat and MVPA was 16.04 ± 7.67% and 297 ± 443 min/week for boys, and 23.41 ± 4.91% and 169 ± 333 min/week for girls, respectively. The prevalence of childhood overweight and physical activity are shown on Table 4.4. According to IOTF BMI cutoff standards, 17.2% students (22.1% boys, 12.4% girls, respectively) were overweight. Among all students participated in the study, only 15.3% (21.8% boys and 9.1% girls, respectively) reported that they met the WHO PA guideline of accumulating 60 minutes of MVPA daily. Boys had better cardiovascular fitness (in terms of PACER score) (41.19 ± 15.93) than girls (21.68 ± 7.47).

Correlations. Correlations between variables were generated so as to further understand their inter-relationship. As age is a known covariate of body fat in students, age-adjusted correlations between variables were computed and are shown in Table 4.5 (boys) and Table 4.6 (girls). Significant correlations ($p<0.01$) were found between percent body fat and BMI (.805), attitude (.155), intention (.115), family exercise participation (.109), population density (.110), and PACER (-.449) for boys, and BMI (.682), attitude (.168), intention (.212), homework (.101), screen time (.130) and PACER (-.276) for girls.

Multilevel models. ***Null Model (Model 1).*** The details of the results generated from the models are shown on the Covariance Parameter Estimates (Table 4.7). ICC of the outcome variable of body fat percentage was 11%, which was statistically significant. That indicated that 11% of the variability in student body fat percentage was attributable to between district differences.

Level 1 (Individual Level) Model (Model 2). The details of the models are shown on Table 4.8, 4.9 and 4.10. Age ($p<.0001$), sex ($p<.0001$) and intention ($p<.0001$) were the only significant level 1 predictors of student's body composition. MVPA did not associate with body composition. Boys have significantly lower body fat percentage compared to girls. Students with higher intention to PA had lower percentage boy fat. Other individual level variables (i.e. MVPA, time spent on homework, screen time, sleep quality and family exercise participation) were not significant predictors of the percentage body fat of students ($p>0.05$). None of the random effects were significant in our analyses ($p>0.05$).

L1 + L2 Model (Model 3). Besides age, gender and intention, NO_2, O_3, and SO_2 were significant predictors of body fat. The relationships, however, did not vary between districts. MVPA, time spent on homework and family income were not significant correlates of students' body fat percentage in this model.

PACER Model (Model 4). Among all models, this model performed the best in terms of model fit. Age, sex, PACER and all air pollutants were significant predictors of body fat percentage. Intention, in this model, was no longer a significant correlate.

Discussion

In the current study, we explored the individual-level as well as district-level correlates of obesity among adolescents in Hong Kong through a citywide population survey and census data (Specific Aim 4). We found that the prevalence of childhood overweight in Hong Kong in 2010-

Table 4.3

Descriptive statistics of the physical and demographic characteristics of the participants.

	Total (n=2517)			Boys (n=1238)			Girls (n=1279)		
	Mean	Range		Mean	Range		Mean	Range	
	(±*SD*)	Min	Max	(±*SD*)	Min	Max	(±*SD*)	Min	Max
Age (years)	15.65 (1.71)	13	19	15.75 (1.76)	13	19	15.56 (1.65)	13	19
BMI (kg/m^2)	20.48 (3.62)	12.97	46.91	20.86 (3.98)	13.37	46.91	20.11 (3.20)	12.97	40.61
Percent body fat (%)	19.84 (7.41)	2.58	56.52	16.04 (7.67)	2.58	56.52	23.47 (4.91)	11.17	44.35
Time spent homework	2.82 (1.28)	1	5	2.57 (1.26)	1	5	3.07 (1.26)	1	5
Screen time	3.47 (1.51)	1	6	3.49 (1.52)	1	6	3.44 (1.50)	1	6
Family income	3.59 (1.63)	0	8	3.57 (1.69)	0	8	3.61 (1.56)	0	8
MVPA (min/week)	231.66 (395.68)	0	3780	296.58 (442.62)	0	3780	169.40 (333.20)	0	3780
Attitude	1.73 (0.77)	1	4	1.57 (0.78)	1	4	1.89 (0.72)	1	4
Intention	2 (0.80)	1	3	1.81 (0.80)	1	3	2.18 (0.75)	1	3
Sleep quality	2.92 (0.91)	1	5	2.86 (0.93)	1	5	2.97 (0.89)	1	5
Family exercise participation	1.94 (1.21)	1	4	1.87 (1.18)	1	4	2.00 (1.23)	1	4
Resting HR (beats/min)	81.20 (13.87)	36	138	78.32 (14.25)	36	134	83.94 (12.92)	53	138
PACER score	31.23 (15.74)	7	111	41.19 (15.93)	10	111	21.68 (7.471)	7	81

Note. Time spent doing homework: 1-5 scale, 1 = <30 minutes, 2 = 30-59 minutes, 3 = 60-119 minutes, 4 = 120-179 minutes, 5 = >180 minutes; Screen time = Student's daily screen time (1-6 scale, 1 = <30 minutes, 2 = 30-59 minutes, 3 = 60-119 minutes, 4 = 120-179 minutes, 5 = 180-239 minutes, 6 = >240 minutes); Family income: Per month in Hong Kong Dollars (1-10 scale, 1 = no income, 2 = ≤$4,999, 3 = $5,000-$9,999, 4 = $10,000-$19,999, 5 = $20,000-$29,999, 6 = $30,000-$39,999, 7 = $40,000-$49,999, 8 = $50,000-$59,999, 9 = $60,000-$99,999, 10 = ≥$100,000) (1US Dollar = 7.75HK Dollars); Attitude = Student's attitude towards PA (1-3 scale, 1 = high, 2 = medium, 3 = low); Intention = Student's intention to engage in PA (1-3 scale, 1 = high, 2 = medium, 3 = low) ; Sleep quality: 1-5 scale, 1 = very bad, 2 = bad, 3 = normal, 4 = good, 5 = very good; family exercise participation: 1-4 scale, 1 = none, 2 = once per several months, 3 = 1-2 times per month, 4 = at least once per week.

Table 4.4

Prevalence of overweight and physical activity among participants

	Percentages		
Parameters	Overall	Boys	Girls
Childhood overweight (according to IOTF standards)	17.2%	22.1%	12.4%
Met WHO PA guidelines (60 minutes of MVPA daily)	15.3%	21.8%	9.1%

Note. The International Obesity Taskforce (IOTF) established an international BMI cutoff for childhood overweight and obesity (Cole et al., 2000) based on six large nationally representative cross-sectional growth studies worldwide. The cutoff points were generated by extrapolation from adult BMI cut off of 25 kg/m2 and 30 kg/m2 for overweight and obesity.

Table 4.5

Age-adjusted Correlation matrix between percentage body fat and other variables for boys

	fat	BMI	MVPA	PACER	Intent-ion	attitude	Home-work	screen	income	sleep	family	popden	NO_2	O_3	PM_{10}	SO_2
fat	1.000															
BMI	**.805**[a]	1.000														
MVPA	-.007	.088	1.000													
PACER	**-.449**[a]	**-.303**[a]	**.263**[a]	1.000												
Intention	**.115**[a]	.007	**-.231**[a]	**-.397**[a]	1.000											
Attitude	**.155**[a]	.086	**-.220**[a]	**-.216**[a]	**.378**[a]	1.000										
Homework	.007	.043	.044	-.067	**.146**[a]	.061	1.000									
screen	.014	.070	.010	-.075	.049	-.032	**-.155**[a]	1.000								
income	-.011	.020	.017	.037	-.092	.005	.016	-.029	1.000							
sleep	-.030	.026	.045	.007	.104	**.124**[a]	**.116**[a]	**.120**[a]	-.040	1.000						
family	**.109**[a]	.049	.070	-.058	-.041	-.021	.019	**-.142**[a]	**.180**[a]	**-.118**[a]	1.000					
popden	**.110**[a]	.058	-.065	**-.142**[a]	**.151**[a]	-.027	**.158**[a]	-.061	-.039	.021	-.008	1.000				
NO_2	.033	.083	-.004	.037	.060	.031	-.070	.028	-.077	-.086	-.003	**.492**[a]	1.000			
O_3	-.020	-.072	-.003	-.052	-.072	-.065	.013	.002	.027	.057	-.026	**-.498**[a]	**-.953**[a]	1.000		
PM_{10}	-.041	.013	-.010	**.140**[a]	.043	-.014	**-.109**[a]	.048	-.098	**-.110**[a]	-.033	**.180**[a]	**.788**[a]	**-.700**[a]	1.000	
SO_2	-.031	-.049	.000	**.127**[a]	.033	**.115**[a]	**.151**[a]	**-.174**[a]	**.206**[a]	-.024	**.196**[a]	-.008	-.008	**-.323**[a]	-.044	1.000

Note. [a] Statistically significant, $p < 0.05$. fat: Percent body fat; BMI: Body mass index; MVPA: Moderate to vigorous physical activity; PACER: PACER test score; Homework: Time spent doing homework; screen: Screen time; income: Family income; sleep: Sleep quality; family: Family exercise participation; popden: Population density.

Table 4.6

Age-adjusted Correlation matrix between percentage body fat and other variables for girls

	fat	BMI	MVPA	PACER	Intent-ion	attitude	Home-work	screen	income	sleep	family	popden	NO2	O3	PM10	SO2
fat	1.000															
BMI	**.682**[a]	1.000														
MVPA	-.053	-.025	1.000													
PACER	**-.276**[a]	**-.201**[a]	**.229**[a]	1.000												
Intention	**.212**[a]	.093	**-.242**[a]	**-.370**[a]	1.000											
Attitude	**.168**[a]	.050	**-.123**[a]	**-.255**[a]	**.440**[a]	1.000										
Homework	**.101**[a]	.027	.045	-.049	-.006	.012	1.000									
screen	**.130**[a]	.049	.062	**-.130**[a]	-.017	.004	-.088	1.000								
income	-.069	-.024	-.078	**.134**[a]	-.040	-.008	.063	-.080	1.000							
sleep	-.010	.036	.060	-.059	.017	.044	**.103**[a]	.087	**-.110**[a]	1.000						
family	-.044	-.016	.062	.086	**-.140**[a]	**-.125**[a]	.054	-.054	.072	-.051	1.000					
popden	-.068	-.090	-.084	-.080	.004	.051	.021	-.091	.045	-.055	.013	1.000				
NO_2	.020	.093	.019	.042	-.009	.020	**-.103**[a]	.045	-.022	-.058	-.045	**.168**[a]	1.000			
O_3	.011	-.091	-.045	-.029	.017	.002	**.101**[a]	-.076	.081	.040	.023	-.060	**-.900**[a]	1.000		
PM_{10}	.002	**.117**[a]	.065	.031	-.074	-.068	-.092	**.142**[a]	**-.137**[a]	.002	-.003	**-.139**[a]	**.827**[a]	**-.868**[a]	1.000	
SO_2	-.052	.000	.047	-.048	.010	.013	.011	.071	**-.112**[a]	.027	.021	-.094	-.088	**-.324**[a]	.094	1.000

Note. [a] Statistically significant, $p < 0.05$. fat: Percent body fat; BMI: Body mass index; MVPA: Moderate to vigorous physical activity; PACER: PACER test score; Homework: Time spent doing homework; screen: Screen time; income: Family income; sleep: Sleep quality; family: Family exercise participation; popden: Population density.

Table 4.7

Covariance Parameter Estimates table

Covariance Parameter Estimates				
Covariance Parameter	Estimate	Standard error	Z Value	Pr > Z
Intercept	6.0088	2.1292	2.82	0.0024
Residual	48.6883	1.4029	34.71	<.0001

Note. Intraclass correlation coefficient (ICC) = 6.0088 / (6.0088 + 48.6883) = 0.11.

Table 4.8

Null and level 1 model showing variance accounted for students' percent body fat by level 1 predictors. The level 1 R^2 of 0.30 shows that the decrease in prediction error for students' percent body fat by Level 1 predictors is 30%.

Model	$\hat{\sigma}^2$	$\hat{\tau}_0^2$	$\hat{\sigma}^2 + \hat{\tau}_0^2$	R_1^2
Null	48.6883	6.0088	54.6971	-
L1 model	38.2072	0.2282	38.4354	0.30

Note. $\hat{\sigma}^2$ = within-group (residual) variance. $\hat{\tau}_0^2$ = between-group (intercept) variance. $R_1^2 = 1 - \frac{38.4354}{54.6971} = 0.30$.

Table 4.9

Level 1 plus level 2 model showing variance accounted for school mean percent body fat by level 2 predictors. The proportional reduction in mean squared prediction error for school mean body fat percentage in the model is 95%.

Model	$\hat{\sigma}^2$	$\hat{\tau}_0^2$	$\hat{\sigma}^2/n + \hat{\tau}_0^2$	R_2^2
Null	48.6883	6.0088	6.3724	-
L1+L2 model	38.1905	0.02384	0.3091	0.95

Note. $\hat{\sigma}^2$ = within-group (residual) variance. $\hat{\tau}_0^2$ = between-group (intercept) variance. Harmonic mean (n) = 133.90. $R_2^2 = 1 - \frac{0.3091}{6.3724} = 0.95$.

Table 4.10
Estimates from multilevel Models Predicting body fat percentage (N = 2,805) (Entries show parameter estimates with standard errors in parentheses)

	Model 1 Null Model	Model 2 L1 Model	Model 3 L1 + L2 Model	Model 4 PACER Model
Fixed Effects				
Intercept	**19.92***	**19.77***	0.62	6.33
	(0.60)	**(0.17)**	(6.88)	(7.24)
Age		**-0.78***	**-0.78***	**-0.57***
		(0.08)	**(0.08)**	**(0.08)**
Sex		**-6.70***	**-6.84***	**-3.65***
		(0.31)	**(0.30)**	**(0.34)**
MVPA		-0.00	-0.00	
		(0.00)	(0.00)	
PACER				**-0.19***
				(0.013)
Intention		**1.19***	**1.17***	0.038
		(0.18)	**(0.18)**	(0.18)
Homework		0.14	0.14	0.18
		(0.11)	(0.11)	(0.10)
Screen time		0.12	0.13	0.086
		(0.09)	(0.09)	(0.09)
Sleep		-0.21	-0.19	-0.10
		(0.15)	(0.15)	(0.14)
Family		0.19	0.17	0.21
		(0.11)	(0.11)	(0.11)
Pop. Density			-0.00	-0.00
			(0.00)	(0.00)
NO_2			**0.11***	**0.13***
			(0.03)	**(0.04)**
O_3			**0.24***	**0.20***
			(0.08)	**(0.08)**
PM_{10}			-0.01	**-0.11***
			0.05	**(0.05)**
SO_2			**0.24***	**0.24***
			(0.08)	**(0.08)**
District mean income			0.00 (0.00)	0.00 (0.00)

Error Variance				
Level 1	**48.69***	**38.21***	**38.09***	**31.77***
	(1.40)	**(1.16)**	**(1.16)**	**(0.99)**
Level 2 Intercept	**6.01***	0.23	0.03	0.03
	(2.13)	(0.18)	(0.12)	(0.13)
MVPA			0.00	
			(0.00)	
PACER				0.00
				(0.00)
Model Fit				
-2 Log Likelihood	16368.8	14293.7	14278.0	13269.5
AIC	16374.8	14315.7	14316.0	13307.5
BIC	16377.5	14325.5	14332.9	13324.4

Note. *Statistically significant, $p < .05$. Values based on SAS Proc Mixed. Estimation Method = ML; Kenward-Roger degrees of freedom. AIC: Akaike information criterion. BIC: Bayesian information criterion.

2011 was 17.2% (22.1% for boys; 12.4% for girls, respectively), based on the data from the Hong Kong Community Fitness Survey 2011. A study conducted between 2001-2006 among similar population (elementary and high school students in Hong Kong; n=29731) using the same IOTF cutoff standard of childhood overweight (Yeung & Hui, 2008) found that the prevalence of childhood overweight was 18.9% and 15.5% for boys and girls, respectively. Compared to the results of current study, while the prevalence for girls went down, the prevalence of boys increased. Compared to other studies adopting the IOTF standards, the prevalence of adolescent overweight in Hong Kong is lower than Europe (López-Sánchez et al., 2019) but higher than mainland China (Gordon-Larsen, Wang, & Popkin, 2014).

We also found that only 15.3% of our sample reported that they met the WHO PA guideline of accumulating 60 minutes of MVPA daily, which was lower than the global figure (19.7%, data summarized from 105 countries) (Hallal et al., 2012). These findings show that childhood overweight and insufficient physical activity are indeed serious health problems among adolescents in Hong Kong. It gives a warning sign to the governments and public health professionals in all developed cities in China, especially for those metropolitan cities located in the southeastern coast of China.

Significant age-adjusted correlations were found between percent body fat (by skinfold thickness) with BMI, attitude, intention and cardiovascular fitness (PACER) for both sexes. BMI is widely used as a crude predictor and indicator of body composition, including the US CDC (Ogden et al., 2014), and is a risk factor for cardiovascular disease (Freedman, Horlick, & Berenson, 2013). Nonetheless, the correlation between percent body fat by skinfold for girls was lower (r=.682) compared to that of boys (r=.805). While BMI provides a quick and convenient way to predict body composition, alternative body composition measurement might be preferred if resource (i.e. time, skilled testers and equipment) is available.

It is quite surprising that body fat percentage did not associate with MVPA. Nonetheless, it related to with PACER and intention. The significant association between percent body fat and intention supported our hypothesis that modifying these individual level psychosocial correlates are important in tackling childhood obesity. Age, sex, PACER, and district NO_2 concentration were the variables remained in the final multilevel model, and were significant predictors of body composition of students in Hong Kong. Compared to MVPA, PACER score was found to be a better predictor of students' body composition. PACER was the indicator of students' cardiovascular fitness, while results IPAQ provide students' MVPA in recent 7 days. IPAQ might not truly reflect general PA habit of students. The self-report nature of IPAQ might also contribute to such results. Another possible explanation is cardiovascular fitness might play a more important role than PA in lowering body fat percentage in students, or cardiovascular fitness is the mediator in the relationship between PA and body composition. From our study findings, on-field cardiovascular fitness test or objective PA measurement could be a better method of surveillance, compared to self-reported PA questionnaire.

Although not one of the significant predictors in the multilevel model, we found significant correlation between family's PA participation and students' body fat percentage. Ornelas and colleagues previously found that parental engagement positively predicted MVPA for both genders (OR [95%CI] = 1.25 [1.17–1.33] for boys, 1.23 [1.14–1.33] for girls) (Ornelas et al., 2007). Our findings also supports the findings in a systematic review of family-based models for childhood-obesity intervention (Sung-Chan, Sung, Zhao, & Brownson, 2013): that family played an important role in modifying the lifestyles of overweight students. In our correlational analysis, the variable family's PA participation significantly correlated with student's intention and attitude towards PA. The above findings could be explained by applying the Reasoned Action Approach (RAA). Parent's participation could enhance their children's intention to engage in PA via improving children's attitude, subjective norm and self-efficacy.

Most of the air pollutants (NO_2, O_3, and SO_2) that we included in the study were significant predictors of students' body fat percentage. A similar finding was found in another study done on Chinese children (Dong et al., 2013). Consistent and significant interactions between exposure and obesity on respiratory symptoms and asthma were found (Dong et al., 2013). It found that the associations between pollutant's yearly concentrations and respiratory symptoms and asthma were consistently larger for overweight/obese children than for normal weight children. In adults, Dubowsky and colleagues (2006) found that concurrent diabetic, obese, and hypertensive patients exhibited large positive associations between ambient NO_2, and inflammation markers like C-reactive protein (CRP) and IL-6. Brook and colleagues (Brook, Jerrett, Brook, Bard, & Finkelstein, 2008) identified a significant relationship between NO_2 and type 2 diabetes among women. Overweight and obese participants also had more asthma symptoms associated with NO_2 exposure than normal-weight participants (Lu et al., 2013). Apart from pathophysiology, air pollution might lower the participation of outdoor leisure-time physical activity (Cerin et al., 2013), which might in turn promote overweight and obesity.

Surprisingly, district population density and mean family income were found not correlates of MVPA nor body fat percentage. Despite their increasing recognition as determinants of PA (C. Lee & Moudon, 2004; Rao, Prasad, Adshead, & Tissera, 2007; Srinivasan, O'Fallon, & Dearry, 2003), our data show no relationship between the variables. A recent systematic review (Bancroft et al., 2015) concluded that in terms of population density or built environment, no consistent pattern of results were found relating park exposure to objectively measured physical activity. More effort is needed to further investigate the environmental and social-economic effects on adolescent obesity.

An important part of this study is to show inter-district variability in the outcome measures by incorporating a multilevel modelling approach. This population-based study combined citywide survey and fitness test data with statistics from the Census and Statistics Department as well as the Environmental Protection Department of Hong Kong. Random sampling was utilized to sample students from every district of Hong Kong, which improved representativeness of the results. The findings are generalizable to students aged 13-19 years in Hong Kong. Our data show sufficient evidence of district level variation in student's body fat percentage. The sizes of the intraclass correlation (11%) suggest clustering or district effects existed in relation to student's body fat percentage. Taking the clustering effect into account, researchers and practitioners can consider about the efficacy of focusing interventions on district instead of individuals, and the need to advocate for more district-centered resource provision for tackling the problem of obesity, or other health-related outcomes. Researchers and public health professionals should also take district or community factors into account when designing health promotion programs. For example, a community-based program involving stakeholders of different levels (i.e. students, parents, teachers and headmasters for school-based programs) at different stages of the program would be beneficial to achieve both physiological and educational effects to the community as a whole.

There are several limitations in this study. First, the results of the study were only generalizable to high school students in Hong Kong and adolescents in other countries but shared similar characteristics. Second, IPAQ, which is a quick and inexpensive tool, was used to track participants' MVPA in current study. However, due to its self-report nature, it is prone to recall bias and social desirability bias (Gagné & Godin, 2005; Hawkshead & Krousel-Wood, 2007). Accelerometer measurement would be a more objective way to track students PA, though that might significantly increase the cost of the study and would probably affect the study sample size. Nonetheless, no matter self-reported questionnaire or accelerometer was used, participant's recent 7-day PA would be recorded in most studies. Whether that was representative to the participant's PA habit is questionable. Compared to previous weeks, participants might have a different PA pattern in the most recent 7 days. That causes the 7-day record unable to truly reflect participants' trend of PA.

Due to the limitations of available data, a cross-sectional design was utilized in this study. Causal relationship between PA and obesity was unable to be investigated in such design. A cohort study design could be used to track students' health status, health behaviors and related variables in a long-term basis. In Hong Kong, most students would stay in the same school from Primary 1 to Primary 6 (i.e. Grade 1-6), and Secondary 1 to Secondary 6 (i.e. Grade 7-12). That offers an ideal environment for researchers to collect longitudinal data from a group of students. Measurement of psychosocial variables should be in more detail in order to further understand about students intention to engage in PA. Some constructs of RAA (i.e. norms, self-efficacy) were not measured in current questionnaire. A specific instrument should be developed and administered to measure those psychosocial factors in a more comprehensive manner.

Insufficient data was available in the dataset to analyze the effect of fine particulate matter ($PM_{2.5}$), another possible correlate, on childhood obesity in our sample. The Environmental Protection Department of Hong Kong did not provide the $PM_{2.5}$ data in the year of 2011 for all districts. Several studies suggest the connection between $PM_{2.5}$ and obesity. In a diet-induced murine model, ambient $PM_{2.5}$ induced obesity to potentiate insulin resistance, visceral adiposity and inflammation, which was associated with increases in systemic TNF-α and IL-6 levels (Sun et al., 2009). Insulin resistance is also characterized by abnormal insulin signaling through the protein kinase B (Akt) pathway (Potera, 2014). Reduced phosphorylation of this enzyme is associated with inflammation (Shao, Yamashita, Qiao, & Friedman, 2000). In human studies, a study conducted in Mexico City found that in a group of children, TNF-α positively associated with 24- and 48-hour cumulative levels of $PM_{2.5}$, while the 7-day $PM_{2.5}$ value was negatively associated with the numbers of white blood cells in peripheral blood in highly exposed children (Calderón-Garcidueñas et al., 2008). More studies need to be done in this area. Local Environmental Protection Departments should routinely collect and release $PM_{2.5}$ data so researchers can use these environmental / ambient air pollution data in their analyses.

In our dataset, missing data was found in family income. Many participants did not report their family income. Because of that, district mean household income was used in our analysis. Researchers need to find a way to encourage the report of individual family income, such as to further ensure the confidentiality of information with participants, so we can analyze to better understand the effect of SES on childhood obesity.

There are several implications of our findings. First, from an epidemiological and measurement perspective, we found that compared to self-reported MVPA, cardiovascular fitness was found to be a better predictor of students' body composition. On-field cardiovascular fitness test (e.g. PACER test) or objective PA measurement (e.g. pedometers, accelerometer or GPS) might be a better method of surveillance. Second, in terms of intrapersonal level of the socio-ecological level, family might play a role in modifying the lifestyles of overweight students. Future school or community weight loss interventions for adolescents should involve their family members as well. Third, speaking of public policy level, improving local and regional air quality could be an effective mean to contain the epidemic of childhood obesity.

Chapter 5

Conclusion

In this dissertation, a meta-analysis was conducted on studies that measured RAA-based variables (intention, attitude, subjective norms and self-efficacy / perceived behavioral control), and PA in children and adolescents. Our results support that intention is a significant correlate and had an medium effect on PA in children. We also aimed to examine the effect size between attitude, subjective norms, perceived behavioral control / self-efficacy, and intention to engage in PA among children and adolescents. Medium to large effects were found between these RAA-based constructs. Such results support that RAA is a viable conceptual framework to study psychosocial factors that underpin physical activity.

On the other hand, we found that there were insufficient studies available to allow meta-analysis to be done on the complete RAA model. The significance of proximal determinants of RAA, such as behavioral beliefs, evaluation of consequences, normative beliefs, motivation to comply, control beliefs, and perceived power, as well as skills and abilities, environmental factors, and other factors, should not be overlooked. Future studies should further investigate these upstream and peripheral factors as well. A specific questionnaire could also be developed to study the amount of MVPA and the determinants of participating in of MVPA, including all RAA-based variables, in children and adolescents.

Moreover, about half of the available studies in our meta-analysis, when investigating the problem of obesity and insufficient PA in children and adolescents, were in a form of cross-sectional study. Evidence from literature utilizing experimental or quasi-experimental studies is limited. These study designs should be utilized in future studies to investigate the causal relationship between constructs. Future interventions should also be carefully designed following the principles of RAA, targeting to improve the psychosocial / intrapersonal, interpersonal, and community level determinants of physical activity and obesity in children. Another possible study direction is to conduct longitudinal cohort studies or secondary analysis in this area. In Hong Kong, most students stay in the same school from Primary 1 to Primary 6, and from Secondary 1 to Secondary 6, which provides a favorable setting for cohort studies. The incidence of obesity can be compared between the exposed and unexposed group. The proposed studies would allow researchers to investigate the temporal effect and possible causal relationship between the determinants via data from cohort studies or longitudinal dataset in pediatric sectors, such as schools and hospitals.

We also examined the effect modifications of certain variables between RAA-based variables and PA. Based on our findings, while age and sex did not modify the relationships between attitude, subjective norms, perceived behavioral control / self-efficacy and intention, geographical region of study was found to be an effect modifier of subjective norm-intention as well as perceived behavioral control / self-efficacy - intention relationship. From this piece of finding, we understand that PA intervention and promotion programs should be tailor-made for the specific population and the country / region of interest. When an intervention was found successful in dealing with a health problem, health promotors and practitioners in other places in the world might be tempted to replicate that study and adopt it to their setting directly. The replicate often found not as successful as compared to the original intervention. Health professionals need to understand the specific attributes, habits and values of the target population, and make modifications and adjustments to the original intervention based on these characteristics. Also, cross-regional or cultural comparison should be examined to explore how

RAA-based intervention performs in different settings in the context of PA promotion among children and adolescents. Apart from that, the direct and indirect environmental effects should be further investigated in obesity and physical activity behavior studies.

In terms of theory development, future research should attempt to incorporate other factors (such as air pollution suggested from the result in Chapter 4) into existing models in order to improve the prediction ability. As mentioned in Chapter 2, theorists and behavioral scientists should notify other researchers to recognize the strengths and weakness of current theories of health behavior, and should not be reluctant to refine or revise the theories (Beauchamp et al., 2019; Rothman, 2004). For example, Hagger and colleagues (2009) suggested the integration of RAA and self-determination theory in health behavior context. These initiatives would help formulate a better understanding of what needs to be done to improve the quality of the theories and to reflect the phenomenon of the dynamic world.

In terms of measurement of PA and obesity in children and adolescents, further effort is required to refine the validity, reliability of both measurements, and to make the measurement more accessible. Future studies should rely on objective measures of PA instead of self-reported measures. Measurement of children's cardiovascular fitness would be a good alternative, or complement, of PA, especially if objective measures of PA is not available. Future studies could further investigate whether PA or cardiovascular fitness, or both, is a better protective factor of child and adolescent obesity.

APPENDICES

Appendix A

Population density of Hong Kong by district in 2011. Data was downloaded from Hong Kong Census and Statistics Department website (www.censtatd.gov.hk).

Population Density by District Council District, 2001, 2006 and 2011 (A202)

District Council District	Population Density (number of persons per km^2)		
	2001	2006	2011 (1)
Hong Kong Island			
Central and Western	21 137	20 102	20 057
Wan Chai	16 986	15 788	15 477
Eastern	33 147	31 664	31 686
Southern	7 482	7 083	7 173
Sub-total	16 775	15 915	15 924
Kowloon			
Yau Tsim Mong	40 932	40 136	44 045
Sham Shui Po	37 772	39 095	40 690
Kowloon City	38 059	36 178	37 660
Wong Tai Sin	47 810	45 540	45 181
Kwun Tong	49 861	52 123	55 204
Sub-total	43 201	43 033	44 917
New Territories			
Kwai Tsing	21 578	22 421	21 901
Tsuen Wan	4 566	4 679	4 918
Tuen Mun	5 919	6 057	5 882
Yuen Long	3 242	3 858	4 178
North	2 184	2 055	2 228
Tai Po	2 287	2 156	2 181
Sha Tin	9 157	8 842	9 173
Sai Kung	2 535	3 135	3 368
Islands	498	783	807
Sub-total	3 526	3 748	3 870
Land total	6 237	6 352	6 544

Note: (1) The boundary of District Council (DC) District refers to that adopted for the DC Election held on 6 November 2011 while the land area used for compiling the population density figures refers to that provided by the Lands Department for the position as at end June 2011.

Source : 2011 Population Census Office
Census and Statistics Department
The Government of the Hong Kong Special Administrative Region
(Enquiry telephone no.: 2716 8025, email: census@censtatd.gov.hk)

Last revision date : 21 February 2012

Appendix B

Air pollution data and domestic household income of Hong Kong by district in 2011. Air pollution data was downloaded with Hong Kong Environmental Protection Department website (www.epd.gov.hk). Household income data was downloaded from Hong Kong Census and Statistics Department website (www.censtatd.gov.hk).

District	NO2 (μg/m^3)	O_3 (μg/m^3)	RSP (μg/m^3)	SO_2 (μg/m^3)	Monthly domestic household income (in HK Dollars)
Sham Shui Po	70	31	51	17	16280
Kwun Tong	63	37	49	12	15960
Tuen Mun	54	39	54	13	18000
Yuen Long	54	39	54	13	18000
Sai Kung	45	48	46	8	26870
Tsuen Wan	64	31	50	16	24100
Wan Chai	124	13	66	10	36150
Yau Tsim Mong	120	11	55	12	22070
Eastern	59	46	43	8	25400
Tai Po	45	48	46	8	22340
Kowloon city	70	31	51	17	23560
North	45	48	46	8	18580
Central/Western	123	16	62	14	33000
Wong Tai Sin	70	31	51	17	17000
Kwai Ching	67	28	48	21	17000
South	59	46	43	8	25700
Shatin	45	43	47	14	23040
Islands	51	44	47	13	21000

REFERENCES OF STUDIES INCLUDED IN META-ANALYSIS (STUDY 1)

Araujo-Soares, V., Sniehotta, F. F., Laing, C. M., Gellert, P., Jackson, D., & Speakman, J. R. (2015). Social cognitions measured in 4 to 6 year olds are predictive of objectively measured physical activity. *Psychology & Health, 30*(10), 1240-1257. doi:10.1080/08870446.2015.1041395

Armitage, C. J., & Sprigg, C. A. (2010). The roles of behavioral and implementation intentions in changing physical activity in young children with low socioeconomic status. *Journal of Sport & Exercise Psychology, 32*(3), 359-376.

Baker, C. W., Little, T. D., & Brownell, K. D. (2003). Predicting adolescent eating and activity behaviors: the role of social norms and personal agency. *Health Psychology, 22*(2), 189-198.

Barkoukis, V., Hagger, M. S., Lambropoulos, G., & Tsorbatzoudis, H. (2010). Extending the trans-contextual model in physical education and leisure-time contexts: examining the role of basic psychological need satisfaction. *British Journal of Educational Psychology, 80*(Pt 4), 647-670. doi:10.1348/000709910x487023

Belanger-Gravel, A., & Godin, G. (2010). Key beliefs for targeted interventions to increase physical activity in children: analyzing data from an extended version of the theory of planned behaviour. *International Journal of Pediatrics, 2010*, 893854. doi:10.1155/2010/893854

Cao, D. S., Schuz, N., Xie, G. R., & Lippke, S. (2013). Planning skills moderate the intention-planning cognitions-behaviour relation: a longitudinal study on physical activity in Chinese adolescents. *Research in Sports Medicine, 21*(1), 12-23. doi:10.1080/15438627.2012.738441

Christodoulos, A. D., Douda, H. T., Polykratis, M., & Tokmakidis, S. P. (2006). Attitudes towards exercise and physical activity behaviours in Greek schoolchildren after a year long health education intervention. *British Journal of Sports Medicine, 40*(4), 367-371. doi:10.1136/bjsm.2005.024521

Craig, S., Goldberg, J., & Dietz, W. H. (1996). Psychosocial correlates of physical activity among fifth and eighth graders. *Preventive Medicine: An International Journal Devoted to Practice and Theory, 25*(5), 506-514. doi:http://dx.doi.org/10.1006/pmed.1996.0083

Dishman, R. K., Saunders, R. P., Felton, G., Ward, D. S., Dowda, M., & Pate, R. R. (2006). Goals and intentions mediate efficacy beliefs and declining physical activity in high school girls. *American Journal of Preventive Medicine, 31*(6), 475-483. doi:10.1016/j.amepre.2006.08.002

Foley, L., Prapavessis, H., Maddison, R., Burke, S., McGowan, E., & Gillanders, L. (2008). Predicting physical activity intention and behavior in school-age children. *Pediatric Exercise Science, 20*(3), 342-356.

Gonzalez-Cutre, D., Sicilia, A., Beas-Jimenez, M., & Hagger, M. S. (2014). Broadening the trans-contextual model of motivation: A study with Spanish adolescents. *Scandinavian Journal of Medicine & Science in Sports, 24*(4), e306-319. doi:10.1111/sms.12142

Guinn, B., Vincent, V., Dugas, D., Semper, T., Jorgensen, L., & Nelson, L. (2006). Exercise Locus of Control, Behavior, and Intention Among Mexican American Youth. *Hispanic Journal of Behavioral Sciences, 28*(1), 115-126. doi:http://dx.doi.org/10.1177/0739986305283635

Hamilton, K., Warner, L. M., & Schwarzer, R. (2016). The Role of Self-Efficacy and Friend Support on Adolescent Vigorous Physical Activity. *Health Education & Behavior*.

doi:10.1177/1090198116648266

Hamilton, K., & White, K. M. (2008). Extending the theory of planned behavior: the role of self and social influences in predicting adolescent regular moderate-to-vigorous physical activity. *Journal of Sport and Exercise Psychology, 30*(1), 56-74.

Hashim, H. A., Jawis, M. N., Wahat, A., & Grove, J. R. (2014). Children's exercise behavior: the moderating role of habit processes within the theory of planned behavior. *Psychology, Health & Medicine, 19*(3), 335-343. doi:10.1080/13548506.2013.808751

Keats, M. R., Culos-Reed, S. N., Courneya, K. S., & McBride, M. (2007). Understanding physical activity in adolescent cancer survivors: an application of the theory of planned behavior. *Psychooncology, 16*(5), 448-457. doi:10.1002/pon.1075

Kerner, M. S., & Kurrant, A. B. (2003). Psychosocial correlates to high school girls' leisure-time physical activity: a test of the theory of planned behavior. *Perceptual and Motor Skills, 97*(3 Pt 2), 1175-1183. doi:10.2466/pms.2003.97.3f.1175

Martin, J. J., McCaughtry, N., & Shen, B. (2008). Predicting physical activity in Arab American school children. *Journal of Teaching in Physical Education, 27*(2), 205-219.

Martin, J. J., Oliver, K., & McCaughtry, N. (2007). The theory of planned behavior: predicting physical activity in Mexican American children. *Journal of Sport and Exercise Psychology, 29*(2), 225-238.

Motl, R. W., Dishman, R. K., Ward, D. S., Saunders, R. P., Dowda, M., Felton, G., & Pate, R. R. (2002). Examining social-cognitive determinants of intention and physical activity among black and white adolescent girls using structural equation modeling. *Health Psychology, 21*(5), 459-467.

Murnaghan, D. A., Blanchard, C. M., Rodgers, W. M., LaRosa, J. N., MacQuarrie, C. R., MacLellan, D. L., & Gray, B. J. (2010). Predictors of physical activity, healthy eating and being smoke-free in teens: A theory of planned behaviour approach. *Psychology & Health, 25*(8), 925-941. doi:http://dx.doi.org/10.1080/08870440902866894

Plotnikoff, R. C., Lubans, D. R., Costigan, S. A., & McCargar, L. (2013). A test of the theory of planned behavior to predict physical activity in an overweight/obese population sample of adolescents from Alberta, Canada. *Health Education & Behavior, 40*(4), 415-425. doi:http://dx.doi.org/10.1177/1090198112455642

Raudsepp, L., Viira, R., & Hannus, A. (2010). Prediction of physical activity intention and behavior in a longitudinal sample of adolescent girls. *Perceptual and Motor Skills, 110*(1), 3-18. doi:10.2466/pms.110.1.3-18

Reynolds, K. D., Killen, J. D., Bryson, S. W., Maron, D. J., Taylor, C. B., Maccoby, N., & Farquhar, J. W. (1990). Psychosocial predictors of physical activity in adolescents. *Preventive Medicine, 19*(5), 541-551.

Rhodes, R. E., Macdonald, H. M., & McKay, H. A. (2006). Predicting physical activity intention and behaviour among children in a longitudinal sample. *Social Science & Medicine, 62*(12), 3146-3156. doi:10.1016/j.socscimed.2005.11.051

Roberts, V., Maddison, R., Magnusson, J., & Prapavessis, H. (2010). Adolescent physical activity: does implementation intention have a role? *Journal of physical activity & health, 7*(4), 497-507.

Sallis, J. F., Alcaraz, J. E., McKenzie, T. L., & Hovell, M. F. (1999). Predictors of change in children's physical activity over 20 months: Variations by gender and level of adiposity. *American Journal of Preventive Medicine, 16*(3), 222-229. doi:http://dx.doi.org/10.1016/S0749-3797(98)00154-8

Tessier, D., Sarrazin, P., Nicaise, V., & Dupont, J. P. (2015). The effects of persuasive communication and planning on intentions to be more physically active and on physical activity behaviour among low-active adolescents. *Psychology & Health, 30*(5), 583-604. doi:10.1080/08870446.2014.996564

Thomas, E., & Upton, D. (2014). Automatic and motivational predictors of children's physical activity: integrating habit, the environment, and the Theory of Planned Behavior. *Journal of physical activity & health, 11*(5), 999-1005. doi:10.1123/jpah.2012-0095

Trost, S. G., Pate, R. R., Dowda, M., Ward, D. S., Felton, G., & Saunders, R. (2002). Psychosocial correlates of physical activity in white and African-American girls. *Journal of Adolescent Health, 31*(3), 226-233.

Trost, S. G., Saunders, R., & Ward, D. S. (2002). Determinants of physical activity in middle school children. *American Journal of Health Behavior, 26*(2), 95-102.

Tsorbatzoudis, H. (2005). Evaluation of a school-based intervention programme to promote physical activity: an application of the theory of planned behavior. *Perceptual and Motor Skills, 101*(3), 787-802. doi:10.2466/pms.101.3.787-802

Wallhead, T. L., Garn, A. C., & Vidoni, C. (2014). Effect of a sport education program on motivation for physical education and leisure-time physical activity. *Research Quarterly for Exercise and Sport, 85*(4), 478-487. doi:10.1080/02701367.2014.961051

Wallhead, T. L., Hagger, M., & Smith, D. T. (2010). Sport education and extracurricular sport participation: an examination using the trans-contextual model of motivation. *Research Quarterly for Exercise and Sport, 81*(4), 442-455. doi:10.1080/02701367.2010.10599705

Wang, L., & Wang, L. (2015). Using Theory of Planned Behavior to Predict the Physical Activity of Children: Probing Gender Differences. *BioMed Research International, 2015*, 536904. doi:10.1155/2015/536904

Wang, L., & Zhang, Y. (2016). An extended version of the theory of planned behaviour: the role of self-efficacy and past behaviour in predicting the physical activity of Chinese adolescents. *Journal of Sports Sciences, 34*(7), 587-597. doi:10.1080/02640414.2015.1064149

REFERENCES

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*, 1–33.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour*. Englewood Cliffs, N.J.: Prentice-Hall.

American College of Sports Medicine. (2005). *ACSM's Guidelines for Exercise Testing and Prescription* (7th ed.). Baltimore, MD: Lippincott Williams & Wilkins.

Ar-yuwat, S., Clark, M. J., Hunter, A., & James, K. S. (2013). Determinants of physical activity in primary school students using the health belief model. *Journal of Multidisciplinary Healthcare*, *6*, 119. https://doi.org/10.2147/JMDH.S40876

Bancroft, C., Joshi, S., Rundle, A., Hutson, M., Chong, C., Weiss, C. C., … Lovasi, G. (2015). Association of proximity and density of parks and objectively measured physical activity in the United States: A systematic review. *Social Science & Medicine*, *138*, 22–30. https://doi.org/10.1016/j.socscimed.2015.05.034

Bandura, A. (1986). *Social Foundations of Thought and Action: a Social·Cognitive Theory.*

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education & Behavior : The Official Publication of the Society for Public Health Education*, *31*(2), 143–164. https://doi.org/10.1177/1090198104263660

Barreira, T. V, Katzmarzyk, P. T., Johnson, W. D., & Tudor-Locke, C. (2013). Walking cadence and cardiovascular risk in children and adolescents: NHANES, 2005-2006. *American Journal of Preventive Medicine*, *45*(6), e27-34.

https://doi.org/10.1016/j.amepre.2013.08.005

Bassuk, S. S., & Manson, J. E. (2005). Epidemiological evidence for the role of physical activity in reducing risk of type 2 diabetes and cardiovascular disease. *Journal of Applied Physiology (Bethesda, Md. : 1985)*, *99*(3), 1193–1204. https://doi.org/10.1152/japplphysiol.00160.2005

Beauchamp, M. R., Crawford, K. L., & Jackson, B. (2019). Social cognitive theory and physical activity: Mechanisms of behavior change, critique, and legacy. *Psychology of Sport and Exercise*, *42*, 110–117. https://doi.org/10.1016/j.psychsport.2018.11.009

Billisari, A., & Roche, A. F. (2005). *Anthropometry and ultrasound* (pp. 109–127). pp. 109–127.

Black, A. E., Coward, W. A., Cole, T. J., & Prentice, A. M. (1996). Human energy expenditure in affluent societies: an analysis of 574 doubly-labelled water measurements. *European Journal of Clinical Nutrition*, *50*(2), 72–92. Retrieved from http://europepmc.org/abstract/med/8641250

Brook, R. D., Jerrett, M., Brook, J. R., Bard, R. L., & Finkelstein, M. M. (2008). The relationship between diabetes mellitus and traffic-related air pollution. *Journal of Occupational and Environmental Medicine*, *50*(1), 32–38. https://doi.org/10.1097/JOM.0b013e31815dba70\r00043764-200801000-00011 [pii]

Butte, N. F., Ekelund, U., & Westerterp, K. R. (2012). Assessing physical activity using wearable monitors: measures of physical activity. *Medicine and Science in Sports and Exercise*, *44*(1 Suppl 1), S5-12. https://doi.org/10.1249/MSS.0b013e3182399c0e

Cain, K. L., Sallis, J. F., Conway, T. L., Van Dyck, D., & Calhoon, L. (2013). Using Accelerometers in Youth Physical Activity Studies: A Review of Methods. *Journal of*

Physical Activity and Health, *10*(3), 437–450. https://doi.org/10.1123/jpah.10.3.437

Calderón-Garcidueñas, L., Villarreal-Calderon, R., Valencia-Salazar, G., Henríquez-Roldán, C., Gutiérrez-Castrellón, P., Torres-Jardón, R., … Reed, W. (2008). Systemic Inflammation, Endothelial Dysfunction, and Activation in Clinically Healthy Children Exposed to Air Pollutants. *Inhalation Toxicology*, *20*(5), 499–506. https://doi.org/10.1080/08958370701864797

Cerin, E., Lee, K., Barnett, A., Sit, C. H. P., Cheung, M., & Chan, W. (2013). Objectively-measured neighborhood environments and leisure-time physical activity in Chinese urban elders. *Preventive Medicine*, *56*(1), 86–89. https://doi.org/10.1016/j.ypmed.2012.10.024

China Physical Fitness Surveillance Center. (2005). *Handbook of the 2005 China National Fitness Surveillance Project*. China Physical Fitness Surveillance Center, General Administration of Sport of China.

Cole, T. J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*, *320*(7244), 1240. https://doi.org/10.1136/bmj.320.7244.1240

Colley, R. C., Garriguet, D., Janssen, I., Craig, C. L., Clarke, J., & Tremblay, M. S. (2011). Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Reports*, *22*(1), 15–23. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21510586

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., … Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise*, *35*(8), 1381–1395.

https://doi.org/10.1249/01.MSS.0000078924.61453.FB

Cureton, K. J., Plowman, S. A., & Mahar, M. T. (2013). FITNESSGRAM / ACTIVITYGRAM Reference Guide. In *The Cooper Institute*.

de Onis, M., Blössner, M., & Borghi, E. (2010). Global prevalence and trends of overweight and obesity among preschool children. *The American Journal of Clinical Nutrition*, *92*(5), 1257–1264. https://doi.org/10.3945/ajcn.2010.29786.1

Demerath, E. W., Guo, S. S., Chumlea, W. C., Towne, B., Roche, A. F., & Siervogel, R. M. (2002). Comparison of percent body fat estimates using air displacement plethysmography and hydrodensitomery in adults and children. *International Journal Obesity Related Metabolic Disorder*, Vol. 26, pp. 389–397.

Dewit, O., Fullera, N. J., Fewtrell, M. S., Elia, M., & Wells, J. C. (2000). Whole body air displacement plethysmography compared with hydrodensitometry for body composition analysis. *Archives of Disease in Childhood*, Vol. 82, pp. 159–164. https://doi.org/10.1136/adc.82.2.159

Dong, G. H., Qian, Z., Liu, M.-M., Wang, D., Ren, W.-H., Fu, Q., … Trevathan, E. (2013). Obesity enhanced respiratory health effects of ambient air pollution in Chinese children: the Seven Northeastern Cities study. *International Journal of Obesity*, *37*(1), 94–100. https://doi.org/10.1038/ijo.2012.125

Dubowsky, S. D., Suh, H., Schwartz, J., Coull, B. A., & Gold, D. R. (2006). Diabetes, obesity, and hypertension may enhance associations between air pollution and markers of systemic inflammation. *Environmental Health Perspectives*, *114*(7), 992–998. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16835049

Dyrstad, S. M., Hansen, B. H., Holme, I. M., & Anderssen, S. A. (2014). Comparison of Self-reported versus Accelerometer-Measured Physical Activity. *Medicine & Science in Sports & Exercise*, *46*(1), 99–106. https://doi.org/10.1249/MSS.0b013e3182a0595f

Dzewaltowski, D. A., Noble, J. M., & Shaw, J. M. (1990). Physical Activity Participation: Social Cognitive Theory versus the Theories of Reasoned Action and Planned Behavior. *Journal of Sport and Exercise Psychology*, *12*(4), 388–405. https://doi.org/10.1123/jsep.12.4.388

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ*, *315*(7109). Retrieved from http://www.bmj.com/content/315/7109/629.short

Ekmekcioglu, C., & Haber, P. (2002). A simple running test to estimate cardiorespiratory fitness. *Journal of Exercise Physiology Online*, *5*(3), 6–13. Retrieved from https://www.researchgate.net/publication/267362724

Eston, R. G., Rowlands, A. V., & Ingledew, D. K. (1998). Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children's activities. *J Appl Physiol*, *84*(1), 362–371. Retrieved from http://jap.physiology.org/content/84/1/362.short

Fields, D a, & Goran, M. I. (2000). Body composition techniques and the four-compartment model in children. *Journal of Applied Physiology (Bethesda, Md. : 1985)*, *89*(2), 613–620. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10926645

Fields, David, Goran, M., & McCrory, M. (2002). Body-composition assessment via air-displacement plethysmography in adults and children: a review. *American Journal of Clinical Nutrition*, *75*(3), 453–467. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11864850

Fishbein, M. (1980). A theory of reasoned action: Some applications and implications. In H. E. Howe & M. M. Page (Eds.), *1979 Nebraska symposium of motivation* (pp. 65–116). Lincoln: University of Nebraska Press.

Fishbein, M. (2008). A reasoned action approach to health promotion. *Medical Decision Making*, *28*(6), 834–844. https://doi.org/10.1177/0272989X08326092

Fishbein, M., & Ajzen, I. (2010). *Predicting and changing behavior: A reasoned action approach.* New York: Psychology Press.

Flegal, K. M., Carroll, M. D., Kit, B. K., & Ogden, C. L. (2012). Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010. *JAMA : The Journal of the American Medical Association*, *307*(5), 491–497. https://doi.org/10.1001/jama.2012.39

Freedman, D. S., Horlick, M., & Berenson, G. S. (2013). A comparison of the Slaughter skinfold-thickness equations and BMI in predicting body fatness and cardiovascular disease risk factor levels in children. *American Journal of Clinical Nutrition*, *98*(6), 1417–1424. https://doi.org/10.3945/ajcn.113.065961

Gagné, C., & Godin, G. (2005). Improving self-report measures of non-adherence to HIV medications. *Psychology & Health*, *20*(6), 803–816. https://doi.org/10.1080/14768320500386441

Gordon-Larsen, P., Wang, H., & Popkin, B. M. (2014). Overweight dynamics in Chinese children and adults. *Obesity Reviews*, *15*, 37–48. https://doi.org/10.1111/obr.12121

Graves, J. E., Pollock, M. L., Colvinl, A. B., Loan, M. V. A. N., & Lohman, T. G. (2005). *Comparison of different bioelectrical impedance analyzers in the prediction of body* *composition*. 1–9.

Guh, D. P., Zhang, W., Bansback, N., Amarsi, Z., Birmingham, C. L., & Anis, A. H. (2009). The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. *BMC Public Health*, *9*, 88. https://doi.org/10.1186/1471-2458-9-88

Hagger, M., & Chatzisarantis, N. (2009). Integrating the theory of planned behaviour and self-determination theory in health behaviour: A meta-analysis. *British Journal of Health …*, 275–303. https://doi.org/10.1348/13S910708X3739S9

Hajer, G. R., van Haeften, T. W., & Visseren, F. L. J. (2008). Adipose tissue dysfunction in obesity, diabetes, and vascular diseases. *European Heart Journal*, *29*(24), 2959–2971. https://doi.org/10.1093/eurheartj/ehn387

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*, *380*(9838), 247–257. https://doi.org/10.1016/S0140-6736(12)60646-1

Harsha, D. W., Frerichs, R. R., & Berenson, G. S. (1978). Densitometry and anthropometry of black and white children. *Human Biology*, Vol. 50, pp. 261–280.

Hashimoto, K., Wong, W. W., Thomas, A. J., Uvena-Celebrezze, J., Huston-Pressley, L., Amini, S. B., & Catalano, P. M. (2002). Estimation of neonatal body composition: Isotope dilution versus total-Body electrical conductivity. *Biology of the Neonate*, Vol. 81, pp. 170–175.

Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., … Bauman, A. (2007). Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*, *116*, 1081–1093.

Hawkshead, J., & Krousel-Wood, M. A. (2007). Techniques for Measuring Medication Adherence in Hypertensive Patients in Outpatient Settings. *Disease Management & Health Outcomes*, *15*(2), 109–118. https://doi.org/10.2165/00115677-200715020-00006

Heyward, H. V. (2001). ASEP methods recommendation: Body coposition assessment. *Journal of Exercise Physiology Online*, Vol. 4, pp. 1–12.

Heyward, H. V. (2006). *Advanced Fitness Assessment and exercise Prescription*.

Heyward, H. V, & Stolarczyk, L. M. (1996). *Applied body composition assessment*.

Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *BMJ*, *327*(7414), 557–560. https://doi.org/10.1136/bmj.327.7414.557

Hochbaum, G., Kegels, S., & Rosenstock, I. (1952). *Health Belief Model*. Washington, DC: US Public Health Service.

Hoffer, E. C., Meador, C. K., & Simpson, D. C. (1969). Correlation of whole-body impedance with total body water volume. *Journal of Applied Physiology*, Vol. 27, pp. 531–534.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hunter, J. E., & Schmidt, F. L. (1990). Dichotomization of continuous variables: The implications for meta-analysis. *Journal of Applied Psychology*, *75*(3), 334–349. https://doi.org/10.1037/0021-9010.75.3.334

Hunter, J. E., & Schmidt, F. L. (2004). *Methods of meta-analysis : correcting error and bias in* *research findings*. Sage.

Huse, D., Patterson, P., & Nichols, J. (2000). The Validity and Reliability of the 12-Minute Swim Test in Male Swimmers Ages 13-17. *Measurement in Physical Education and Exercise Science*, *4*(1), 45–55. https://doi.org/10.1207/S15327841Mpee0401_5

Hwang, M. I., & Schmidt, F. L. (2011). Assessing moderating effect in meta-analysis: a re-analysis of top management support studies and suggestions for researchers. *European Journal of Information Systems*, *20*(6), 693–702. https://doi.org/10.1057/ejis.2011.12

Janssen, I., Heymsfield, S. B., Allison, D. B., Kotler, D. P., & Ross, R. (2002). Body mass index and waist circumference independently contribute to the prediction of nonabdominal, abdominal subcutaneous, and visceral fat. *American Journal of Clinical Nutrition*, *75*(4), 683–688. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11916754

Ji, C. Y., & Sun, J. (2004). Analyses of the epidemiological status of overweight and obesity in Chinese students and the prevalence changes in recent 15 years. *Journal of Peking University (Health Sciences)*, *36*, 194–197.

Joseph, D. A., DeGroff, A. S., Hayes, N. S., Wong, F. L., & Plescia, M. (2011). The Colorectal Cancer Control Program: partnering to increase population level screening. *Gastrointestinal Endoscopy*, *73*(3), 429–434. https://doi.org/10.1016/j.gie.2010.12.027

Kelly, L. A., Reilly, J. J., Fisher, A., Montgomery, C., Williamson, A., McColl, J. H., … Grant, S. (2006). Effect of socioeconomic status on objectively measured physical activity. *Archives of Disease in Childhood*, *91*(1), 35–38. https://doi.org/10.1136/adc.2005.080275

Kriska, A. M., Saremi, A., Hanson, R. L., Bennett, P. H., Kobes, S., Williams, D. E., & Knowler, W. C. (2003). Physical Activity, Obesity, and the Incidence of Type 2 Diabetes in a High-

Risk Population. *American Journal of Epidemiology*, *158*(7), 669–675. https://doi.org/10.1093/aje/kwg191

Kuczmarski, R. J., Ogden, C. L., Guo, S. S., Grummer-Strawn, L. M., Flegal, K. M., Mei, Z., … Johnson, C. L. (2002). 2000 CDC Growth Charts for the United States: methods and development. *Vital and Health Statistics. Series 11, Data from the National Health Survey*, (246), 1–190. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12043359

Laaksonen, D. E., Lindstrom, J., Lakka, T. A., Eriksson, J. G., Niskanen, L., Wikstrom, K., … Uusitupa, M. (2005). Physical Activity in the Prevention of Type 2 Diabetes: The Finnish Diabetes Prevention Study. *Diabetes*, *54*(1), 158–165. https://doi.org/10.2337/diabetes.54.1.158

Lachat, C. K., Verstraeten, R., Nguyen, L., Khanh, B., Hagströmer, M., Khan, N. C., … Kolsteren, P. W. (2008). Validity of two physical activity questionnaires (IPAQ and PAQA) for Vietnamese adolescents in rural and urban areas. *International Journal of Behavioral Nutrition and Physical Activity*, *5*(37), 1–8. https://doi.org/10.1186/1479-Received

LaForgia, J., Ploeg, G. E., Withers, R. T., Gunn, S. M., Brooks, A. G., & VChatterton, B. E. (2004). Impact of indexing resting metabolic rate against fat-free mass determined by different body composition models. *European Journal of Clinical Nutrition*, Vol. 58, pp. 1132–1141.

Lear, S. A., Humphries, K. H., Kohli, S., & Birmingham, C. L. (2007). The Use of BMI and Waist Circumference as Surrogates of Body Fat Differs by Ethnicity**. *Obesity*, *15*(11), 2817–2824. https://doi.org/10.1038/oby.2007.334

Lee, C., & Moudon, A. V. (2004). Physical Activity and Environment Research in the Health Field: Implications for Urban and Transportation Planning Practice and Research. *Journal of Planning Literature*, *19*(2), 147–181. https://doi.org/10.1177/0885412204267680

Lee, I.-M., & Shiroma, E. J. (2014). Using accelerometers to measure physical activity in large-scale epidemiological studies: issues and challenges. *British Journal of Sports Medicine*, *48*(3), 197–201. https://doi.org/10.1136/bjsports-2013-093154

Lee, I.-M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., & Katzmarzyk, P. T. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*, *380*(9838), 219–229. https://doi.org/10.1016/S0140-6736(12)61031-9

Lee, P. H., Macfarlane, D. J., Lam, T. H., & Stewart, S. M. (2011). Validity of the International Physical Activity Questionnaire Short Form (IPAQ-SF): a systematic review. *The International Journal of Behavioral Nutrition and Physical Activity*, *8*(1), 115. https://doi.org/10.1186/1479-5868-8-115

Lee, R. L. T., Lee, P. H., Sze, D. M. Y., & Chien, W. T. (2017). Anthropometric profile of Hong Kong children and adolescents: the Wellness Population of Youth Study. *Journal of the American Society of Hypertension*, *11*(4), 196-203.e4. https://doi.org/10.1016/J.JASH.2017.01.007

Léger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences*, *6*(2), 93–101. https://doi.org/10.1080/02640418808729800

Leung, S. S. (1995). Childhood Obesity in Hong Kong. *The Hong Kong Journal of Paediatrics*, pp. 63–68.

Leung, S. S., Lau, J. T., Tse, L. Y., & Oppenheimer, S. J. (1996). Weight-for-age and weight-for-height references for Hong Kong children from birth to 18 years. *Journal of Paediatrics and Child Health*, Vol. 32, pp. 103–109.

Leung, S. S., Ng, M. Y., Lau, T. F., & Tse, L. Y. (1995). Prevalence of Obesity in Hong Kong Children and Adlescents Aged 3-18 Years. *Chinese Journal of Preventive Medicine*, Vol. 29, pp. 270–272.

Leung, S. S., Tse, L. Y., & Leung, N. K. (1996). Growth and Nutrition in Hong Kong children. *Singapore Paediatric Journal*, Vol. 38, pp. 61–66.

Li, F., Liu, Y., Lü, J., Liang, L., & Harmer, P. (2015). Ambient air pollution in China poses a multifaceted health threat to outdoor physical activity. *Journal of Epidemiology and Community Health*, *69*(3), 201–204. https://doi.org/10.1136/jech-2014-203892

Lohman, T. G., & Chen, Z. (2005). *Dual X-Ray Absorptiometry* (pp. 63–77). pp. 63–77.

López-Sánchez, G. F., Sgroi, M., D'Ottavio, S., Díaz-Suárez, A., González-Víllora, S., Veronese, N., & Smith, L. (2019). Body Composition in Children and Adolescents Residing in Southern Europe: Prevalence of Overweight and Obesity According to Different International References. *Frontiers in Physiology*, *10*, 130. https://doi.org/10.3389/fphys.2019.00130

Loprinzi, P. D., & Cardinal, B. J. (2011). Measuring Children's Physical Activity and Sedentary Behaviors. *Journal of Exercise Science & Fitness*, *9*(1), 15–23. https://doi.org/10.1016/S1728-869X(11)60002-6

Lu, K. D., Breysse, P. N., Diette, G. B., Curtin-Brosnan, J., Aloe, C., Williams, D. L., … Matsui, E. C. (2013). Being overweight increases susceptibility to indoor pollutants among urban children with asthma. *The Journal of Allergy and Clinical Immunology*, *131*(4), 1017–1023, 1023.e1-3. https://doi.org/10.1016/j.jaci.2012.12.1570

Macfarlane, D. J., Lee, C. C. Y., Ho, E. Y. K., Chan, K. L., & Chan, D. T. S. (2007). Reliability and validity of the Chinese version of IPAQ (short, last 7 days). *Journal of Science and Medicine in Sport / Sports Medicine Australia*, *10*(1), 45–51. https://doi.org/10.1016/j.jsams.2006.05.003

Manson, J. E., Stampfer, M. J., Colditz, G. A., Willett, W. C., Rosner, B., Hennekens, C. H., … Krolewski, A. S. (1991). Physical activity and incidence of non-insulin-dependent diabetes mellitus in women. *The Lancet*, *338*(8770), 774–778. https://doi.org/10.1016/0140-6736(91)90664-B

Masters, R. K., Reither, E. N., Powers, D. A., Yang, Y. C., Burger, A. E., & Link, B. G. (2013). The impact of obesity on US mortality levels: the importance of age and cohort factors in population estimates. *American Journal of Public Health*, *103*(10), 1895–1901. https://doi.org/10.2105/AJPH.2013.301379

Mattocks, C., Ness, A., Leary, S., Tilling, K., Blair, S. N., Shield, J., … Riddoch, C. (2008, October 17). Use of accelerometers in a large field-based study of children: protocols, design issues, and effects on precision. *Journal of Physical Activity and Health*. Retrieved from http://strathprints.strath.ac.uk/33601/

Mayorga-Vega, D., Aguilar-Soto, P., & Viciana, J. (2015). Criterion-Related Validity of the 20-M Shuttle Run Test for Estimating Cardiorespiratory Fitness: A Meta-Analysis. *Journal of*

Sports Science & Medicine, *14*(3), 536–547. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/26336340

Mayorga-Vega, D., Bocanegra-Parrilla, R., Ornelas, M., & Viciana, J. (2016). Criterion-Related Validity of the Distance- and Time-Based Walk/Run Field Tests for Estimating Cardiorespiratory Fitness: A Systematic Review and Meta-Analysis. *PloS One*, *11*(3), e0151671. https://doi.org/10.1371/journal.pone.0151671

Meredith, M. D., & Welk, G. J. (2010). *FitnessGram/ActivityGram : Test Administration Manual* (4th ed.). Retrieved from https://books.google.com.hk/books?hl=en&lr=&id=Gp4NJMX62lQC&oi=fnd&pg=PR1&dq=+FITNESSGRAM+Test+Administration+Manual&ots=gNRMR0G49Y&sig=acN-iPpu0mLJzezUT-hw42zN2wE&redir_esc=y#v=onepage&q=FITNESSGRAM Test Administration Manual&f=false

Mokdad, A. H., Marks, J. S., Stroup, D. F., & Gerberding, J. L. (2004). Actual Causes of Death in the United States, 2000. *JAMA: The Journal of the American Medical Association*, *291*(10), 1238–1245. https://doi.org/10.1001/jama.291.10.1238

Montero, D., Walther, G., Perez-Martin, A., Roche, E., & Vinet, A. (2012). Endothelial dysfunction, inflammation, and oxidative stress in obese children and adolescents: markers and effect of lifestyle intervention. *Obesity Reviews : An Official Journal of the International Association for the Study of Obesity*, *13*(5), 441–455. https://doi.org/10.1111/j.1467-789X.2011.00956.x

Muthén, B., & Muthén, L. (2008). *Mplus user guide*. Los Angeles, CA: Author.

Ng, J. Y. Y., Ntoumanis, N., Thogersen-Ntoumani, C., Deci, E. L., Ryan, R. M., Duda, J. L., &

Williams, G. C. (2012). Self-Determination Theory Applied to Health Contexts: A Meta-Analysis. *Perspectives on Psychological Science*, *7*(4), 325–340. https://doi.org/10.1177/1745691612447309

Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., … Gakidou, E. (2014). Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet (London, England)*, *384*(9945), 766–781. https://doi.org/10.1016/S0140-6736(14)60460-8

Nguyen, N. T., Nguyen, X.-M. T., Lane, J., & Wang, P. (2011). Relationship between obesity and diabetes in a US adult population: findings from the National Health and Nutrition Examination Survey, 1999-2006. *Obesity Surgery*, *21*(3), 351–355. https://doi.org/10.1007/s11695-010-0335-4

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2012). Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. *JAMA : The Journal of the American Medical Association*, *307*(5), 483–490. https://doi.org/10.1001/jama.2012.40

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA : The Journal of the American Medical Association*, *311*(8), 806–814. https://doi.org/10.1001/jama.2014.732

Ogden, C. L., Carroll, M. D., Lawman, H. G., Fryar, C. D., Kruszon-Moran, D., Kit, B. K., & Flegal, K. M. (2016). Trends in obesity prevalence among children and adolescents in the United States, 1988-1994 through 2013-2014. *JAMA - Journal of the American Medical*

Association. https://doi.org/10.1001/jama.2016.6361

Ornelas, I. J., Perreira, K. M., Ayala, G. X., Gordon-Larsen, P., Adair, L., Nelson, M., … Killen, J. (2007). Parental influences on adolescent physical activity: a longitudinal study. *International Journal of Behavioral Nutrition and Physical Activity*, *4*(1), 3. https://doi.org/10.1186/1479-5868-4-3

Otto, T. C., & Lane, M. D. (2008). *Adipose Development: From Stem Cell to Adipocyte*. Retrieved from http://informahealthcare.com/doi/abs/10.1080/10409230591008189

Park, M. H., Falconer, C., Viner, R. M., & Kinra, S. (2012). The impact of childhood obesity on morbidity and mortality in adulthood: a systematic review. *Obesity Reviews : An Official Journal of the International Association for the Study of Obesity*, *13*(11), 985–1000. https://doi.org/10.1111/j.1467-789X.2012.01015.x

Pedišić, Ž., & Bauman, A. (2015). Accelerometer-based measures in physical activity surveillance: current practices and issues. *British Journal of Sports Medicine*, *49*(4), 219–223. https://doi.org/10.1136/bjsports-2013-093407

Permana, P. A., Menge, C., & Reaven, P. D. (2006). Macrophage-secreted factors induce adipocyte inflammation and insulin resistance. *Biochemical and Biophysical Research Communications*, *341*(2), 507–514. https://doi.org/10.1016/j.bbrc.2006.01.012

Plasqui, G., Bonomi, A. G., & Westerterp, K. R. (2013). Daily physical activity assessment with accelerometers: new insights and validation studies. *Obesity Reviews : An Official Journal of the International Association for the Study of Obesity*, *14*(6), 451–462. https://doi.org/10.1111/obr.12021

Pope, C. A., Burnett, R. T., Thurston, G. D., Thun, M. J., Calle, E. E., Krewski, D., & Godleski,

J. J. (2004). Cardiovascular Mortality and Long-Term Exposure to Particulate Air Pollution. *Circulation*, *109*(1), 71–77. https://doi.org/10.1161/01.CIR.0000108927.80044.7F

Pope, C. A., & Dockery, D. W. (2006). Health Effects of Fine Particulate Air Pollution: Lines that Connect. *Journal of the Air & Waste Management Association*, *56*(6), 709–742. https://doi.org/10.1080/10473289.2006.10464485

Potera, C. (2014). Toxicity beyond the Lung: Connecting $PM_{2.5}$, Inflammation, and Diabetes. *Environmental Health Perspectives*, *122*(1). https://doi.org/10.1289/ehp.122-A29

Prochaska, J. O., & Velicer, W. F. (1997). The Transtheoretical Model of Health Behavior Change. *American Journal of Health Promotion*, *12*(1), 38–48. https://doi.org/10.4278/0890-1171-12.1.38

Rao, M., Prasad, S., Adshead, F., & Tissera, H. (2007). The built environment and health. *Lancet (London, England)*, *370*(9593), 1111–1113. https://doi.org/10.1016/S0140-6736(07)61260-4

Reilly, J. J., & Kelly, J. (2011). Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. *International Journal of Obesity*, *35*(7), 891–898. https://doi.org/10.1038/ijo.2010.222

Rosenstock, I. M. (1974). The Health Belief Model and Preventive Health Behavior. *Health Education & Behavior*, *2*(4), 354–386. https://doi.org/10.1177/109019817400200405

Rothman, A. J. (2004). “Is there nothing more practical than a good theory?”: Why innovations and advances in health behavior change will arise if interventions are used to test and refine theory. *International Journal of Behavioral Nutrition and Physical Activity*, *1*(1), 11. https://doi.org/10.1186/1479-5868-1-11

Ruan, H., Hacohen, N., Golub, T. R., Van Parijs, L., & Lodish, H. F. (2002). Tumor Necrosis Factor- Suppresses Adipocyte-Specific Genes and Activates Expression of Preadipocyte Genes in 3T3-L1 Adipocytes: Nuclear Factor- B Activation by TNF- Is Obligatory. *Diabetes*, *51*(5), 1319–1336. https://doi.org/10.2337/diabetes.51.5.1319

Ruiz, J. R., Castro-Piñero, J., Artero, E. G., Ortega, F. B., Sjöström, M., Suni, J., & Castillo, M. J. (2009). Predictive validity of health-related fitness in youth: A systematic review. *British Journal of Sports Medicine*, *43*(12), 909–923. https://doi.org/10.1136/bjsm.2008.056499

Sallis, J. F., Owen, N., & Fisher, E. B. (2008). Ecological Models of Health Behavior. In K. Glanz, B. K. Rimer, & K. Viswanath (Eds.), *Health Behavior and Health Education: Theory, Research, and Practice* (4th Ed., pp. 465–485). https://doi.org/465-482

Sallis, J. F., Prochaska, J., & Taylor, W. (2000). A review of correlates of physical activity of children and adolescents. *Medicine and Science in …*, *32*(5), 963–975. Retrieved from http://www.researchgate.net/publication/12521182_A_review_of_correlates_of_physical_activity_of_children_and_adolescents/file/9fcfd509495ae32123.pdf

SAS Institute. (2011). *SAS/STAT 9.3 User's Guide*. Cary, North Carolina, USA.

Shao, J., Yamashita, H., Qiao, L., & Friedman, J. (2000). Decreased Akt kinase activity and insulin resistance in C57BL/KsJ-Leprdb/db mice. *The Journal of Endocrinology*, *167*(1), 107–115. https://doi.org/10.1677/JOE.0.1670107

Sigal, R. J., Kenny, G. P., Wasserman, D. H., & Castaneda-Sceppa, C. (2004). Physical Activity/Exercise and Type 2 Diabetes. *Diabetes Care*, *27*(10), 2518–2539. https://doi.org/10.2337/diacare.27.10.2518

Sigal, R. J., Kenny, G. P., Wasserman, D. H., Castaneda-Sceppa, C., & White, R. D. (2006).

Physical activity/exercise and type 2 diabetes: a consensus statement from the American Diabetes Association. *Diabetes Care*, *29*(6), 1433–1438. https://doi.org/10.2337/dc06-9910

Slaughter, M. G., Lohman, T. G., Boileau, C. A., Horswill, R. J., Stillman, M. D., Loan, M. D., & Bemben, D. A. (1988). Skinfold equations for estimation of body fatness in children and youth. *Human Biology*, Vol. 660, pp. 709–723.

Sluik, D., Buijsse, B., Muckelbauer, R., Kaaks, R., Teucher, B., Johnsen, N. F., … Nöthlings, U. (2012). Physical Activity and Mortality in Individuals With Diabetes Mellitus: A Prospective Study and Meta-analysis. *Archives of Internal Medicine*, *172*(17), 1285–1295. https://doi.org/10.1001/archinternmed.2012.3130

Snijders, T., & Bosker, R. (1999). Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling. In *http://lst-iiep.iiep-unesco.org/cgi-bin/wwwi32.exe/[in=epidoc1.in]/?t2000=013777/(100)*.

Song, Y., Ma, J., Wang, H.-J., Wang, Z., Hu, P., Zhang, B., & Agard, A. (2015). Secular trends of obesity prevalence in Chinese children from 1985 to 2010: Urban-rural disparity. *Obesity*, *23*(2), 448–453. https://doi.org/10.1002/oby.20938

Sopher, A., Shen, W., & Pietrobelli, A. (2005). *Pediatric Body Composition Methods* (pp. 129–139). pp. 129–139.

Srinivasan, S., O'Fallon, L. R., & Dearry, A. (2003). Creating healthy communities, healthy homes, healthy people: initiating a research agenda on the built environment and public health. *American Journal of Public Health*, *93*(9), 1446–1450. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12948961

Strath, S. J., Kaminsky, L. A., Ainsworth, B. E., Ekelund, U., Freedson, P. S., Gary, R. A., …

Swartz, A. M. (2013). Guide to the assessment of physical activity: Clinical and research applications: a scientific statement from the American Heart Association. *Circulation*, *128*(20), 2259–2279. https://doi.org/10.1161/01.cir.0000435708.67487.da

Suganami, T., Nishida, J., & Ogawa, Y. (2005). A paracrine loop between adipocytes and macrophages aggravates inflammatory changes: role of free fatty acids and tumor necrosis factor alpha. *Arteriosclerosis, Thrombosis, and Vascular Biology*, *25*(10), 2062–2068. https://doi.org/10.1161/01.ATV.0000183883.72263.13

Suganami, T., Tanimoto-Koyama, K., Nishida, J., Itoh, M., Yuan, X., Mizuarai, S., … Ogawa, Y. (2007). Role of the Toll-like receptor 4/NF-kappaB pathway in saturated fatty acid-induced inflammatory changes in the interaction between adipocytes and macrophages. *Arteriosclerosis, Thrombosis, and Vascular Biology*, *27*(1), 84–91. https://doi.org/10.1161/01.ATV.0000251608.09329.9a

Sun, Q., Yue, P., Deiuliis, J. A., Lumeng, C. N., Kampfrath, T., Mikolaj, M. B., … Rajagopalan, S. (2009). Ambient Air Pollution Exaggerates Adipose Inflammation and Insulin Resistance in a Mouse Model of Diet-Induced Obesity. *Circulation*, *119*(4), 538–546. https://doi.org/10.1161/CIRCULATIONAHA.108.799015

Sung-Chan, P., Sung, Y. W., Zhao, X., & Brownson, R. C. (2013). Family-based models for childhood-obesity intervention: a systematic review of randomized controlled trials. *Obesity Reviews*, *14*(4), 265–278. https://doi.org/10.1111/obr.12000

Tandon, P. S., Zhou, C., Sallis, J. F., Cain, K. L., Frank, L. D., & Saelens, B. E. (2012). Home environment relationships with children's physical activity, sedentary time, and screen time by socioeconomic status. *The International Journal of Behavioral Nutrition and Physical*

Activity, *9*(1), 88. https://doi.org/10.1186/1479-5868-9-88

Tanwar, V., Katapadi, A., Adelstein, J. M., Grimmer, J. A., & Wold, L. E. (2018). Cardiac pathophysiology in response to environmental stress: a current review. *Current Opinion in Physiology*, *1*, 198–205. https://doi.org/10.1016/J.COPHYS.2017.11.005

The Chinese University of Hong Kong. (2012). *Healthy Exercise for All Campaign – Physical Fitness Test for the Community Final Summary Report*. Retrieved from https://www.lcsd.gov.hk/en/healthy/physical_fitness_test/common/physical_fitness_test/download/SummaryReport_en.pdf

Tudor-Locke, C., Ainsworth, B. E., Adair, L. S., Du, S., & Popkin, B. M. (2003). Physical activity and inactivity in Chinese school-aged youth: the China Health and Nutrition Survey. *International Journal of Obesity*, *27*(9), 1093–1099. https://doi.org/10.1038/sj.ijo.0802377

Unger, J. B., Reynolds, K., Shakib, S., Spruijt-Metz, D., Sun, P., & Johnson, C. A. (2004). Acculturation, Physical Activity, and Fast-Food Consumption Among Asian-American and Hispanic Adolescents. *Journal of Community Health*, *29*(6), 467–481. https://doi.org/10.1007/s10900-004-3395-3

Van Der Horst, K., Paw, M. J. C. a, Twisk, J. W. R., & Van Mechelen, W. (2007). A brief review on correlates of physical activity and sedentariness in youth. *Medicine and Science in Sports and Exercise*, *39*(8), 1241–1250. https://doi.org/10.1249/mss.0b013e318059bf35

Venables, M. C., & Jeukendrup, A. E. (2009). Physical inactivity and obesity: links with insulin resistance and type 2 diabetes mellitus. *Diabetes/Metabolism Research and Reviews*, *25 Suppl 1*, S18-23. https://doi.org/10.1002/dmrr.983

Viswesvaran, C., & Ones, D. S. (1995). Theory testing: Combining psychometric meta-analysis and structural equations modeling. *Personnel Psychology*, *48*(4), 865–885. https://doi.org/10.1111/j.1744-6570.1995.tb01784.x

Wake, M., Clifford, S. A., Patton, G. C., Waters, E., Williams, J., Canterford, L., & Carlin, J. B. (2013). Morbidity patterns among the underweight, overweight and obese between 2 and 18 years: population-based cross-sectional analyses. *International Journal of Obesity (2005)*, *37*(1), 86–93. https://doi.org/10.1038/ijo.2012.86

Wang, J. J., Gao, Y., & Lau, P. W. C. (2017). Prevalence of overweight in Hong Kong Chinese children: Its associations with family, early-life development and behaviors-related factors. *Journal of Exercise Science and Fitness*, *15*(2), 89–95. https://doi.org/10.1016/j.jesf.2017.10.001

Wang, Y. C., McPherson, K., Marsh, T., Gortmaker, S. L., & Brown, M. (2011). Health and economic burden of the projected obesity trends in the USA and the UK. *Lancet*, *378*(9793), 815–825. https://doi.org/10.1016/S0140-6736(11)60814-3

Wang, Y., & Lobstein, T. (2006). Worldwide trends in childhood overweight and obesity. *International Journal of Pediatric Obesity*, Vol. 1, pp. 11–25. https://doi.org/10.1080/17477160600586747

Wang, Y., Mi, J., Shan, X., Wang, Q. J., & Ge, K. (2006). Is China facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in China. *International Journal of Obesity*, *31*(1), 177–188. https://doi.org/10.1038/sj.ijo.0803354

Weinsier, R. L., Hunter, G. R., Heini, A. F., Goran, M. I., & Sell, S. M. (1998). The etiology of obesity: relative contribution of metabolic factors, diet, and physical activity. *The American*

Journal of Medicine, *105*(2), 145–150. https://doi.org/10.1016/S0002-9343(98)00190-9

Wells, J. C., & Fuller, N. J. (2001). Precision of measurement and body size in whole-body air-displacement plethysmography. *International Journal Obesity Related Metabolic Disorder*, Vol. 25, pp. 1161–1167.

Wolden, M., Hill, B., & Farquhar Voorhees, S. (2019). Meta-analysis in Physical Therapy Education Research. *Journal of Physical Therapy Education*, *33*(1), 78–84. https://doi.org/10.1097/JTE.0000000000000075

World Health Organization. (2010). *Global recommendations on physical activity for health*. Retrieved from http://medcontent.metapress.com/index/A65RM03P4874243N.pdf

World Health Organization. (2014a). *Global status report on noncommunicable diseases 2014*. Retrieved from World Health Organization website: http://apps.who.int//iris/handle/10665/148114

World Health Organization. (2014b). What is Moderate-intensity and Vigorous-intensity Physical Activity? Retrieved January 10, 2019, from WHO website: https://www.who.int/dietphysicalactivity/physical_activity_intensity/en/

Yao, S., & Loo, B. P. Y. (2016). Safety in numbers for cyclists beyond national-level and city-level data: A study on the non-linearity of risk within the city of Hong Kong. *Injury Prevention*. https://doi.org/10.1136/injuryprev-2016-041964

Yeung, D. C., & Hui, S. S. (2007). Evaluation of the 1993 reference criteria for assessing the prevalence of childhood obesity in Hong Kong. *Medicine and Science in Sports and Exercise*, *39*(5S), S378.

Yeung, D. C., & Hui, S. S. (2008). Prevalence of childhood obesity in Hong Kong: Comparison between IOTF and weight-height cut-off standards. *Medicine and Science in Sports and Exercise*, *40*, S2.

Yeung, D. C., & Hui, S. S. (2010). Validity and reliability of skinfold measurement in assessing body fatness of Chinese children. *Asia Pacific Journal of Clinical Nutrition*, *19*(3), 350–357.

Zhao, Y.-F., Feng, D. D., & Chen, C. (2006). Contribution of adipocyte-derived factors to beta-cell dysfunction in diabetes. *The International Journal of Biochemistry & Cell Biology*, *38*(5–6), 804–819. https://doi.org/10.1016/j.biocel.2005.11.008

Daniel Chi Shing Yeung

danyeung@indiana.edu

EDUCATION

Indiana University Bloomington Aug 2019
PhD, Epidemiology
Human Performance Minor
Dissertation: Correlates of Physical Activity and Obesity in Children and Adolescents: A Meta-analysis and Multilevel Analysis of Hong Kong Community Fitness Survey
Advisor: Dr. Aurelian Bidulescu

Indiana University Bloomington Dec 2012
MPH, Behavioral, Social and Community Health

The Chinese University of Hong Kong Jul 2008
MPhil, Sports Science and Physical Education
Thesis: Validity and Reliability of Skinfold Measurement in Assessing Body Density and Body Fatness of Chinese Children in Hong Kong: Using Air Displacement Plethysmography as a Criterion Measure
Advisor: Prof. Stanley Sai-chuen Hui, EdD

The Chinese University of Hong Kong Jul 2006
BEd, Physical Education and Sports Science
Psychology Minor

TEACHING EXPERIENCE

Adjunct Assistant Professor 2013-Present
Department of Health, Hong Kong Adventist College
(Affiliated with Andrews University, MI, USA)

Teaching the following courses:
- FTES465 Exercise Physiology
- FTES305 Concepts and Applications of Physical Fitness
- FTES355 Methods of Fitness Instruction
- FTES210 Personal Fitness Plan
- FTES214 Weight Training
- PEAC130 Special Activity

Lecturer 2017-Present
Talent Identification and Development Team, Hong Kong Sports Institute

Designing and coaching fitness training sessions for Hong Kong junior national athletes

- Artistic Gymnastics Team
- Cycling Team
- Rhythmic Gymnastics Team

Lecturer II 2018-2019
Department of Health and Physical Education, The Education University of Hong Kong

Designing and teaching exercise science and health education-related courses at undergraduate level:

- PES1195 Growth, Development and Ageing
- PES2200 Exercise Physiology
- PES2215 Strength and conditioning
- PES3205 Research Methods in Sports Science
- PES4208 Principles and Practice of Health Promotion
- HCS4043 Health Statistics

Lecturer 2016-2017
Department of Sports and Recreation, Technological and Higher Education Institute of Hong Kong

Teaching the following module:

- MSR5322 Research Methods & Statistics
- MSR5331 Advanced Functional Anatomy & Exercise Physiology
- MSR4102 Sports Skills Development – Team Sports

Strength and Conditioning Coach 2016-2017
Men's Under-18 team, Yuen Long Football Club

Designing and coaching fitness training sessions

Personal Trainer 2015-2016
Indiana University Recreational Sports

Lecturer 2014-2015
Physical Fitness Association of Hong Kong, China

Teaching the following course:

- Physical Fitness Assessment Leader (Advanced Level) Certification Course

Lecturer 2014-2015
Department of Sports Science and Physical Education,

The Chinese University of Hong Kong

Teaching the following course:

- SPED2600B Basic Statistics, Test, and Measurement for Physical Education

Associate Instructor 2009-2013

School of Public Health, Indiana University Bloomington

- HPER-Y654 Advanced Epidemiological Methods lab – Teaching students applying analytic epidemiology methods including analyzing complex descriptive epidemiology, problems of confounding and effect modification, exposure-time relationships, multivariable risk models, meta-analysis, distribution and geographic data applications. Focus on interpretation of findings, study design, analytic approach, and results
- HPER-Y611 Epidemiology – Assisting students to apply epidemiologic principles to evaluate current literature, develop appropriate study design and methods, and strategies to limit threats to validity
- HPER-E119 Personal Fitness Lab – Teaching students about personal fitness program design, implementation and evaluation. It included teaching on goal setting, various exercises and how to set up an exercise program, balanced diet and conducting fitness tests
- HPER-P409 Exercise Physiology Lab – Teaching students conducting data collection for muscular fitness, aerobic fitness and anaerobic power, pulmonary fitness and body composition. It involved utilization of iWorx software, spirometry, hydrostatic weighing, bioelectric impedance analysis (BIA), skinfold measurement, isokinetic machine and various muscular strength and endurance tests

Teaching Assistant 2006-2008

Department of Sports Science and Physical Education, The Chinese University of Hong Kong

- SPE6200 Physical Fitness and Health: Advanced Theories and Application - Teaching students conducting data collection for muscular fitness, aerobic fitness and anaerobic power, pulmonary fitness and body composition. It involved hydrostatic weighing, bioelectric impedance analysis (BIA), skinfold measurement and various muscular strength and endurance tests
- SPE4560 Physical Fitness Assessment and Exercise Prescription – Providing assistance in lectures as well as teaching students about personal fitness program design, implementation and evaluation in tutorial sessions. It included teaching on goal setting, various exercises and how to set up an exercise program, balanced diet and conducting fitness tests

- SPE2600 Basic Measurement, Statistics and Computing in Physical Education – Teaching labs on how to use SPSS software and providing assistance in lectures
- UGD262S Design of Personal Health and Fitness Training Program – Introducing basic knowledge of exercise and personal health as well as assisting students to develop personal muscular training program and aerobic exercise training program

RESEARCH EXPERIENCE

Assistant School Development Officer 2017-2018
Faculty of Education, The Chinese University of Hong Kong

Project title: Promoting physical activity in primary schoolchildren through family-school support and state-of-the-art technology: a social ecological approach

- Working on a project titled "Fun to Move @JC", which was designed to increase primary school students' physical activity using tools in information technology. The project is led by the Faculty of Education, supported by The Hong Kong Jockey Club Charities Trust. Job duties included (a) liaise with school officials to support project implementation in schools; (b) hold regular meetings with school teacher and parent representatives; (c) lead activity classes for students and/or parents; (d) organize teacher professional development workshops for in-service teachers; (e) design and manage project contents, including inter-schools events, under the project; (f) support the project team in data collection in project schools.

Graduate Assistant 2011-2014
School of Public Health, Indiana University Bloomington

Conducting epidemiological research and data analysis, with emphasis on childhood obesity

Research Assistant 2005-2008
Department of Sports Science and Physical Education, The Chinese University of Hong Kong

- Conducting laboratory tests including oxygen uptake measurement during at rest and exercise by operating Cosmed K4b2 gas analyzer and body composition measurement by air displacement plethysmography (Bod Pod) and hydrostatic weighing, and field tests including skinfold measurement
- Analyzing data collected in citywide community and school health and fitness surveys in Hong Kong

- Organizing the International Conference on Childhood Obesity: Evidence and Practice from Exercise Science (13-16 Nov 2008)

OTHER EXPERIENCE

Intern 2011
Health and Wellness Education, Indiana University Health Center

Planning, designing, and implementing health and wellness education programs and campus-wide health education and promotion events

Police Constable (Auxiliary) 2005-2011
Hong Kong Auxiliary Police Force

A support to the regular Police Force in the performance of crowd management duties during major public events and in other pre-planned operations, and acts as a trained manpower reserve to support the regular Force in its daily performance of beat patrol duties and in supplementing normal police services during the policing of major events

PUBLICATIONS

Peer-reviewed Publications

Yeung, D. C. S., Yuan, X., Hui, S. S. C. and Feresu, S. A. (2016). Determinants of moderate to vigorous physical activity and obesity in children: A structural equation modeling analysis. World Journal of Pediatrics, 12(2), 170-176.

Yeung, D. C. S. and Hui, S. S. C. (2010). Validity and reliability of skinfold measurement in assessing body fatness of Chinese children. Asia Pacific Journal of Clinical Nutrition, 19(3), 350-357.

Abstracts and Presentations

Yeung, D. C. S., Bidulescu, A., Hui, S. S. C. (2018) Correlates of Obesity in Adolescents: A Multilevel Analysis of Hong Kong Community Fitness Survey. ISBNPA Annual Meeting 2018, Hong Kong. (Oral presentation)

Yeung, D. C. S., Marker-Hoffman, R. L., Hinman, M. G., Johnston, J. D. (2012). Evaluation of fitness and health behaviors survey in predicting body composition of American college students. *Medicine and Science in Sports and Exercise*, 44 (5S), 872.

Marker-Hoffman, R. L., Johnston, J. D., **Yeung, D. C. S.**, Hinman, M. G., (2012). Relationship of Waist Circumference, Fitness, and Walking in Male and Female College Students. *Medicine and Science in Sports and Exercise*, 44 (5S), 602.

Yeung, D. C. S. and Hui, S. C. (2010). Comparison between four common methods of estimating body fat in Chinese children. *Obesity Reviews*, 11(suppl.), 170.

Yeung, D. C. S.; Tse, M. M.; Johnson, B. D.; Hong, J.; Wallace, J. P. (2010). Does lifestyle account for differences in endothelial function between Asians and Caucasians? *Medicine and Science in Sports and Exercise*, Volume 42(5), 308.

Johnson, B. D.; **Yeung, D. C. S.** ; Hong, J.; Lee, S.; Padilla, J.; Wallace, J. P. (2010) How Do Different Doses Of Acute Aerobic Exercise Affect Post Exercise Endothelial Function? *Medicine and Science in Sports and Exercise*, Volume 42(5), 309.

Hui, S. C. and **Yeung, D. C. S.** (2009). Discrepancy between the IOTF-BMI criteria and the body fat criteria for classifying Chinese childhood obesity. *Medicine and Science in Sports and Exercise*, 41(5), 108.

Yeung, D. C. S. and Hui, S. C., (2008). Prevalence of childhood obesity in Hong Kong: Comparison between IOTF and weight-height cut-off standards. *Medicine and Science in Sports and Exercise*, 40(5)(suppl.), S2. (Oral presentation)

Yeung, D. C. S. and Hui, S. C., (2007). Evaluation of the 1993 Reference Criteria for assessing the prevalence of childhood obesity in Hong Kong. *Medicine and Science in Sports and Exercise*, 39(5)(suppl.), S378.

HONORS AND AWARDS

Graduate Assistantship — 2009-2014
School of Public Health, Indiana University Bloomington

School of Public Health Fellowship – Epidemiology — 2012-2014
School of Public Health, Indiana University Bloomington

School of Public Health Student Travel Grant-In-Aid — 2009, 2010, 2012
School of Public Health, Indiana University Bloomington

CUHK Postgraduate Student Travel Grant — 2007, 2008
The Chinese University of Hong Kong

Postgraduate Studentship — 2006-2008
The Chinese University of Hong Kong

CERTIFICATIONS

American Red Cross Adult CPR/AED/Standard First Aid — Since 2009

Asian Football Confederation (AFC) "C" Coaching License	Since 2007
American College of Sports Medicine (ACSM) Certified Exercise Physiologist	Since 2005
Hong Kong Basketball Association Level 2 Coach	Since 2005

STATISTICAL SOFTWARE PROFICIENCIES

Statistical Package for the Social Science (SPSS)	Proficient
Statistical Analysis System (SAS)	Proficient
MPlus	Proficient
EpiInfo	Proficient

LANGUAGE PROFICIENCIES

Chinese (Cantonese)	Fluent
Chinese (Mandarin)	Fluent

PROFESSIONAL AFFILIATONS

International Society of Behavioral Nutrition and Physical Activity (ISBNPA)	Since 2018
American Association for the Advancement of Science (AAAS)	Since 2014
American College of Sports Medicine (ACSM)	Since 2007